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INSIGHTS ON THE GREEK ECONOMY FROM THE 3D MACRO MODEL

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ABSTRACT

This paper examines the macroeconomic and welfare implications of banking capital requirement policies and their interactions with real and financial shocks for the Greek economy. The model employed is that of Clerc et al. (2015), a DSGE model featuring a detailed financial sector, banking capital regulations and bank default in equilibrium. The key model implication is that capital requirements reduce bank leverage and the default risk of banks but their relationship with social welfare is hump-shaped, reflecting a trade-off. The model is calibrated to data on the Greek economy and the dynamic responses to a number of financial and real shocks which may have played a material role in the unfolding of the Greek crisis are explored. The results indicate *inter alia* that an increase in the depositors' cost of bank default leads to a substantial increase in the deposit rate, a decline in deposits and bank equity and an increase in bank fragility, while on the real side of the economy the decline in total credit prompts a deterioration of key macro variables. Additionally, the results imply that while recapitalizations increase bank net worth and credit supply and boost economic activity, this potential benefit is severely compromised in a high financial distress scenario, as the positive real and financial implications of a recapitalization become both smaller and more short-lived.

Keywords: Macroprudential Policy, General Equilibrium, Greece.
JEL classification: E3, E44, G01, G21, O52.

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1. Introduction

This paper examines the macroeconomic and welfare implications of banking capital requirement policies and their interactions with real and financial shocks for the Greek economy. In doing so, the paper adopts the model of Clerc et al. (2015), a Dynamic Stochastic General Equilibrium (DSGE) model that features a detailed financial sector, banking capital regulations and strategic defaults in equilibrium for three sectors of the economy, namely households, entrepreneurs and banks. We consider the model's ability to fit the Greek data, explore the insights the model provides as regards the linkages between the aforementioned three sectors of the Greek economy and the possibility that each may default and we try to interpret the ongoing economic crisis of Greece through the lens of this new tool. The approach of this paper can be summarized as follows. First, we calibrate the model to the Greek economy in order to match certain features of the data. Then, we examine the long-run effects of banking capital requirements on key model variables, including social welfare. Finally, we study the dynamic responses to a number of financial and real shocks related to the recent Greek experience and explore their transmission mechanisms and interactions with banking capital regulations.

As the linkages between financial and macroeconomic stability are at the forefront of academic attention, there is a growing literature that attempts to incorporate banking sector and financial frictions in DSGE models. The model of Clerc et al. (2015), dubbed the "3D model" to highlight the fact that default is allowed to take place in equilibrium in the three sectors of the economy, is one of the most innovative in this area. Clerc et al. (2015) provide a comprehensive literature review of past modelling approaches which have set the stage for their work (see e.g. Curdia and Woodford, 2010, Gertler and Kiyotaki, 2010, and Gerali et al., 2010). The main reference they draw on in setting up their macroeconomic model is Bernanke, Gertler and Gilchrist (1999), who popularized the costly state verification technology of Towsend (1979) and Gale and Hellwig (1985) by integrating it into a macroeconomic setup. However, the 3D model innovates vis-à-vis the above literature in that it assumes debt default is non-state-contingent, which makes banks exposed to rises in loan default rates caused by aggregate shocks. As regards the evolution of bank balance sheets, the model follows the tradition of Gertler and Kiyiotaki (2010) inter alia, who emphasised the importance of financing constraints for the propagation of shocks. As default costs are reflected in the balance sheets of different sectors, the agents' optimisation process is affected, and hence so is the real economy. The limit on banks' leverage stems from the regulatory capital requirements. In this context, macroprudential policy contains the banks' tendency to over-invest which results from their limited liability to depositors. Through the aforementioned mechanisms, the 3D model is able to provide relatively rich insights into the dynamic linkages between financial stability and real economic activity.

Turning to the academic literature on the Greek economy, Papageorgiou (2012, 2014) and Papageorgiou and Vourvachaki (2016) are the most recent papers calibrating DSGE models to the Greek economy. Indeed, the calibration presented here draws on their insights. Additionally, the Bank of Greece Governor's Annual Reports provide useful overviews of developments in Greece. However, to our knowledge, the links between the Greek financial sector and the macroeconomy have not, to date, been rigorously modelled, partly because prior to the recent crisis they were not of particular interest.

Conversely, in the aftermath of the crisis, the Greek economy is an inherently interesting case study for such a model. The global financial crisis brought to the surface the underlying fragility of an over-indebted country with limited policy options and prompted a domino effect on all sectors of the economy. Government spreads skyrocketed and as a result the Greek banking sector was cut off from the interbank market, in a sharp and protracted liquidity squeeze. Many small banks, faced with the spectre of default, were forced to merge with larger ones. The banking system as a whole was recapitalized several times, in an effort to render it viable and to allow it to resume its role as a mediator between savers and investors. Nonetheless, credit flows continued to decline sharply, as the Greek economy entered into a deep recession which drove many businesses out of the market and a significant part of the labour force into unemployment. As a result, non-performing loans accumulated, causing a vicious circle which, in the absence of access to the interbank market, implied further declines in credit flows and the need for further bank recapitalisation. In sum, in the Greek case, all sectors that are allowed to default in the 3D model faced substantial shocks, which effectively led to defaults over the course of the crisis. Furthermore, the impact of poor macroeconomic performance on financial intermediation was substantial, as was the feedback effect of disrupted financial intermediation on the macroeconomy.

In applying the Clerc et al. (2015) model, our main interest is not to study or justify the use of macroprudential policies *per se* –as was their primary goal– but rather to explore how the mechanics of default may have operated in the case of Greece and their interplay with selected policy tools and risk shocks which are particularly relevant to the Greek crisis experience. As some of these have not, to date, been considered in the 3D context, the present paper is not only a country study, but also an effort to provide some further insights regarding the linkages between macroprudential policies, financial shocks and the real economy.

Our main results are the following. As outlined in Clerc et al. (2015), in this model bank capital regulations reduce bank leverage and the default risk of banks. The relationship between the bank capital requirement ratio and social welfare is hump-shaped, implying an optimal level of capital requirements. This is due to the following trade-off: up to a point, an increase in capital requirements leads to a rise in total credit and a boost in economic activity; however, for high levels of capital requirements, total credit begins to decline, dominating the positive impact of declining bank defaults. In addition, the results show that in the presence of high financial distress, banks are more vulnerable to shocks and their capacity to supply credit is more volatile. Macroprudential policy has a buffering effect on the real economy, as it can smooth the adverse effects of exogenous shocks. Additionally, we explore the implications of applying haircuts to depositors in the case of bank defaults, a scenario which was considered likely during the Greek crisis, and find that both the real and financial repercussions are negative. Finally, in view of the repeated recapitalisations of Greek banks in recent years, we explore the effects of such a positive shock to the banking sector and find that although recapitalizations can indeed have a positive impact on both real and financial variables, these benefits become both smaller and more short-lived under financial distress.

The remainder of the paper is structured as follows: Section 2 presents the 3D model. Section 3 discusses the calibration and long-run solution. Section 4 presents the steady-state analysis, illustrating the dynamics of the model and the effects of different levels of capital requirements. Section 5 presents an impulse response analysis and relates it to the recent Greek experience. Finally, Section 6 concludes.

2. The 3D model[1]

The model economy consists of households, entrepreneurs, and bankers. Households are infinitely lived and consume, supply labour in a competitive market and invest in housing. There are two types of households, patient and impatient, that differ in their subjective discount factor. In equilibrium, patient households are savers and impatient households are borrowers. The latter negotiate limited liability non-recourse mortgage loans from banks using their holdings of housing as collateral. They can individually choose to default on their mortgage, with the only implication of losing the housing units on which the mortgage is secured.

Entrepreneurs are the owners of the physical capital stock and finance their purchases of physical capital with the inherited net worth and corporate loans provided by banks, that are subject to limited liability and default risk.

Bankers are the providers of inside equity to perfectly competitive financial intermediaries, the "banks". The latter provide mortgage and corporate loans that are financed from saving households' deposits and by raising equity from bankers. The banks are subject to regulatory capital constraints and must back a fraction of their loans with equity funding. They operate under limited liability and may default due to both idiosyncratic and aggregate shocks to the performance of their loan portfolios. In the case of a bank default deposits are fully guaranteed by a deposit insurance agency (DIA). However, depositors may pay a risk premium that depends on the default probability of banks, thus raising the funding cost of banks when their default risk is high.

Finally, regarding the production sector, there are perfectly competitive firms that produce the final good and new units of capital and housing.

Households

There are two representative dynasties of ex ante identical infinitely lived households that differ only in the subjective discount factor. One dynasty, indexed by the superscript s, is made up of relatively patient households with a discount factor β^s. The other dynasty, identified by the superscript m, consists of more impatient

[1] This section summarily presents the 3D model of Clerc et al. (2015), following their sections 3 and 4, to facilitate the reader.

households with a discount factor $\beta^m < \beta^s$. In equilibrium, the patient households save and the impatient households borrow from banks.

Saving Households

The dynasty of patient households maximizes

$$E_t\left[\sum_{i=0}^{\infty}(\beta^s)^{t+i}[\log(c_{t+i}^s) + v^s \log(h_{t+i-1}^s) - \frac{\varphi^s}{1+\eta}(l_{t+1}^s)^{1+\eta}\right]$$

subject to

$$c_t^s + q_t^H h_t^s + d_t \leq w_t l_t^s + q_t^H(1-\delta_t^H)h_{t-1}^s + \tilde{R}_t^D d_{t-1} - T_t + \Pi_t^s$$

where c_t^s denotes the consumption of non-durable goods, h_t^s denotes the total stock of housing, l_t^s denotes hours worked, η is the inverse of the Frisch elasticity of labour supply and v^s and φ^s are preference parameters. Also, q_t^H is the price of housing, δ_t^H is the depreciation rate of housing units and w_t is the real wage rate. As owners of the firms, households receive profits, Π_t^s, that are distributed in the form of dividends. $\tilde{R}_t^D$ is defined as $\tilde{R}_t^D = R_{t-1}^D\left(1-\gamma PD_t^b\right)$, where R_t^D is the gross fixed interest rate received at t on the savings and PD_t^b is the economy-wide probability of bank default in period t. In the case of a bank default the principal and the interest of bank deposits are fully guaranteed by a deposit insurance agency (DIA) by imposing a lump-sum tax T_t. However, it is assumed that households face linear transaction costs denoted by γ that create a wedge between the return to deposits and the risk-free interest rate and a link between the probability of default and the cost of funding for the banks. The presence of a deposit risk premium raises the funding cost for banks while, in addition, the fact that this premium depends on the economy-wide default risk rather than on their own default risk induces an incentive for banks to take excessive risk and provides a rationale for macroprudential policy.

Borrowing Households

Impatient households have the same preferences as patient households except for the discount factor, which is $\beta^m < \beta^s$. The budget constraint of the representative dynasty is:

$$c_t^m + q_t^H h_t^m - b_t^m \leq w_t l_t^m + \int_0^\infty \max\{\omega_t^m q_t^H (1-\delta_t^H) h_{t-1}^m - R_{t-1}^m b_{t-1}^m, 0\}\, dF^m(\omega_t^m)$$

where b_t^m is aggregate borrowing from the banks and R_{t-1}^m is the contractual gross interest rate on the housing loan agreed upon in period $t-1$. ω_t^m is an idiosyncratic shock to the efficiency units of housing owned from period $t-1$ that each household experiences at the beginning of each period t. The shock is assumed to be independently and identically distributed across the impatient households and to follow a lognormal distribution with density and cumulative distributions functions denoted by $f(.)$ and $F(.)$, respectively. This shock affects the effective resale value of the housing units acquired in the previous period, $\tilde{q}_t^H = \omega_t^m q_t^H (1-\delta_t^H)$, and makes default on the loan *ex post* optimal for the household whenever $\omega_t^m q_t^H (1-\delta_t^H) h_{t-1}^m < R_{t-1}^m b_{t-1}^m$. The term in the integral reflects the fact that the housing good and the debt secured against it are assumed to be distributed across the individual households that constitute the dynasty.

After the realization of the shock, each household decides whether to default or not on the individuals loans held from the previous period. Then, the dynasty makes the decisions for consumption, housing, labour supply and debt in period t and allocates them evenly across households. As shown in Clerc at al. (2015), individual households default in period t whenever the idiosyncratic shock ω_t^m satisfies:

$$\omega_t^m \leq \overline{\omega}_t^m = \frac{x_{t-1}^m}{R_t^H}$$

where $R_t^H = \frac{q_t^H(1-\delta_t^H)}{q_{t-1}^H}$ is the ex post average realized return on housing and $x_t^m = \frac{R_t^m b_t^m}{q_t^H h_t^m}$ is a measure of household leverage. The net housing equity after accounting for repossessions of defaulting households can be written as:

$\left(1-\Gamma^m(\bar{\omega}_t^m)\right)R_t^H q_{t-1}^H h_{t-1}^m,$

where $\Gamma^m(\bar{\omega}_t^m)=\int_0^{\bar{\omega}_{t+1}^m}(\omega_t^m f^m(\omega_t^m))d\omega_t^m+\bar{\omega}_{t+1}^m\int_{\bar{\omega}_1^m}^{\infty}(f^m(\omega_t^m))d\omega_t^m$ is the share of gross returns (gross of verification costs) accrued by the bank and $\left(1-\Gamma^m(\bar{\omega}_t^m)\right)$ is the share of assets accrued to the dynasty.

Since each of the impatient households can default on its loans, the loans taken in period t should satisfy the participation constraint for the lending banks:

$$E_t(1-\Gamma^H(\bar{\omega}_t^H))(\Gamma^m(\bar{\omega}_{t+1}^m)-\mu^m G^m(\omega_{t+1}^m))R_{t+1}^H q_t^H h_t^m \geq \rho_t \phi_t^H b_t^m$$

The left-hand side of the inequality accounts for the total equity returns associated with a portfolio of housing loans to the various members of the impatient dynasty. The interpretation of the banking participation constraint is that the expected gross return for bankers should be at least as high as the gross equity return of the funding of the loan from the bankers, $\rho_t \phi_t^H b_t^m$, where ρ_t is the required expected rate of return on equity from bankers (defined below) and ϕ_t^H is the capital requirement on housing loans. The term $\mu^m G^m(\omega_{t+1}^m)$ is the expected cost of default, where μ^m is the verification cost and $G^m(\omega_{t+1}^m)=\int_0^{\bar{\omega}_{t+1}^m}(\omega_{t+1}^m f(\omega_{t+1}^m))d\omega_{t+1}^m$ is the share of assets that belong to households that default. Finally, $(1-\Gamma^H(\bar{\omega}_t^H))$ is the share of assets accrued to bankers in the case of a bank default, where $\bar{\omega}_t^H$ is the threshold level to the idiosyncratic shock of banks that specialize in mortgage loans (defined below).

Given the above, the problem of the representative dynasty of the impatient households can be written compactly as a contracting problem between the representative dynasty and its bank. In particular, the problem of the dynasty is to maximize utility subject to the budget constraint and the participation constraint of the bank:

$$\max_{\{c_{t+1}^m,\,h_{t+1}^m,\,l_{t+1}^m,\,x_{t+1}^m,\,b_{t+1}^m\}_{i=0}^{\infty}} E_t\left[\sum_{i=0}^{\infty}(\beta^m)^{t+i}[\log(c_{t+i}^m)+v^m\log(h_{t+i}^m)-\frac{\varphi^m}{1+\eta}(l_{t+1}^m)^{1+\eta}\right]$$

subject to

$$c_t^m + q_t^H h_t^m - b_t^m \leq \omega_t l_t^m + \left(1 - \Gamma^m\left(\frac{x_t^m}{R_{t+1}^H}\right)\right) R_{t+1}^H q_t^H h_t^m$$

and

$$E_t\left[(1 - \Gamma^H(\bar{\omega}_{t+1}^m))\left(\Gamma^m\left(\frac{x_t^m}{R_{t+1}^H}\right) - \mu^m G^m\left(\frac{x_t^m}{R_{t+1}^H}\right)\right) R_{t+1}^H\right] R_{t+1}^H q_t^H h_t^m = \rho_t \phi_t^H b_t^m$$

Entrepreneurs

Entrepreneurs are risk neutral agents that live for two periods. Each generation of entrepreneurs inherits wealth in the form of bequests and purchases new capital from capital good producers and depreciated capital from the previous generation of entrepreneurs, that they rent out to final good producers. They finance capital purchases with their initial wealth and with corporate loans from banks, b_t^e. The entrepreneurs derive utility from the transfers made to the patient households in period $t+1$ (dividends), c_{t+1}^e, and the bequests left to the next cohort of entrepreneurs (retained earnings), n_{t+1}^e, according to the utility function $(c_{t+1}^e)^{\chi^e}(n_{t+1}^e)^{1-\chi^e}$, $\chi^e \in (0,1)$. Thus, the problem of the entrepreneurs in period $t+1$ is:

$$\max_{\{c_{t+1}^e, n_{t+1}^e\}} (c_{t+1}^e)^{\chi^\varepsilon}(n_{t+1}^e)^{1-\chi^e}$$

subject to $c_{t+1}^e + n_{t+1}^e \leq W_{t+1}^e$, where W_{t+1}^e is the wealth resulting from the activity in the previous period.

The optimization problem of the entrepreneur in period t is to maximize expected wealth:

$$\max_{\{k_t, b_t^e, R_t^F\}} E_t(W_{t+1}^e)$$

subject to the period t resource constraint $q_t^K k_t - b_t^e = n_t^e$ and the banks participation constraint (defined below), where $W_{t+1}^e = \max\{\omega_{t+1}^e(r_{t+1}^k + (1-\delta_{t+1})q_{t+1}^K)k_t - R_t^F b_t^e, 0\}$, q_t^K is the price of capital at period t, k_t is the capital held by the entrepreneur in period t, b_t^e is the is the amount borrowed from the bank in period t, r_t^k is the rental rate of capital, δ_t is the depreciation rate of physical capital and R_t^F is the contractual gross interest rate of the corporate loan. ω_{t+1}^e is an idiosyncratic shock to the efficiency units of capital which is independently and identically distributed across entrepreneurs. It is realized after the period t loan with the bank is agreed to and prior to renting the available capital to consumption good producers on that date. Similar to the case of borrowing households, entrepreneurs default on their loans whenever $\omega_{t+1}^e\left(r_{t+1}^k + (1-\delta_{t+1})q_{t+1}^K\right)k_t < R_t^F b_t^e$. As shown in Clerc et al. (2015), the entrepreneur will repay their corporate loan in period $t+1$ whenever the indiosyncratic shock ω_{t+1}^e exceeds the following threshold:

$$\overline{\omega}_{t+1}^e \equiv \frac{R_t^F b_t^e}{R_{t+1}^K q_t^K k_t} \equiv \frac{x_t^e}{R_{t+1}^K}$$

where $R_{t+1}^K = \frac{r_{t+1}^k + (1-\delta_{t+1})q_{t+1}^K}{q_t^K}$ is the gross return per efficiency units of capital in period $t+1$ of capital owned in period t, $x_t^e = \frac{R_t^F b_t^e}{q_t^K k_t}$ denotes the entrepreneurial leverage that is defined as the ratio of contractual debt repayment obligations in period $t+1$, $R_t^F b_t^e$, to the value of the purchased capital at t, $q_t^K k_t$.

Given the above, the maximization problem of the entrepreneurs in period t can be compactly written as:

$$\max_{x_t^e, k_t} E_t[(1 - \Gamma^e\left(\frac{x_t^e}{R_{t+1}^K}\right)) R_{t+1}^K q_t^K k_t]$$

subject to

$$E_t\left[(1-\Gamma^F(\overline{\omega}_{t+1}^F))\left(\Gamma^e(\overline{\omega}_{t+1}^e) - \mu^e G^e(\overline{\omega}_{t+1}^e)\right)\right] R_{t+1}^K q_t^K k_t = \rho_t \phi_t^F (q_t^K k_t - n_t^e)$$

where $\Gamma^e(\overline{\omega}_{t+1}^e) = \int_0^{\overline{\omega}_{t+1}^e} (\omega_{t+1}^e f^e(\omega_{t+1}^e)) d\omega_{t+1}^e + \overline{\omega}_{t+1}^e \int_{\overline{\omega}_{t+1}^e}^{\infty} (f^e(\omega_{t+1}^e)) d\omega_{t+1}^e$ is the share of gross returns that will accrue to the bank, $G^e(\overline{\omega}_{t+1}^e) = \int_0^{\overline{\omega}_{t+1}^e} (\omega_{t+1}^e f^e(\omega_{t+1}^e)) d\omega_{t+1}^e$ is the fraction of the returns coming from the defaulted loans of entrepreneurs, μ^e denotes the verification costs incurred by the bank and $(1-\Gamma^F(\overline{\omega}_t^F))$ is the share of assets accrued to bankers in the case of a bank default, where $\bar{\omega}_t^F$ is the default threshold level for the idiosyncratic shock of banks that specialize in corporate loans (defined below). Similar to the case of impatient households, the interpretation of the participation constraint is that, in equilibrium, the expected return of the corporate loans must equal to the expected rate of return on equity, ρ_t, that the bankers require for their contribution to the funding of loan, $\phi_t^F(q_t^K k_t - n_t^e)$, where ϕ_t^F is the capital requirement applied on corporate loans.

Bankers

Like entrepreneurs, bankers are risk-neutral and live for two periods. They invest their initial wealth, inherited in the form of bequest from the previous generation of bankers, n_t^b, as bank's inside equity capital. In period $t+1$ the bankers derive utility from transfers to the patient households in the form of dividends, c_{t+1}^b, and the bequests left to the next generation of bankers (retained earnings), n_{t+1}^b, according to the utility function $\left(c_{t+1}^b\right)^{\chi^b}\left(n_{t+1}^b\right)^{1-\chi^b}$, where $\chi^b \in (0,1)$. Thus, the problem of the banker in period $t+1$ is:

$$\max_{\{c_{t+1}^b, n_{t+1}^b\}} \left(c_{t+1}^b\right)^{\chi^b}\left(n_{t+1}^b\right)^{1-\chi^b}$$

subject to

$$c_{t+1}^b + n_{t+1}^b \leq W_{t+1}^b$$

where W_{t+1}^b is the wealth of the banker in period $t+1$.

Regarding the decision problem of the bankers in period t, the banker born in period t with initial wealth n_t^b decides how much of this wealth to allocate as inside equity capital across the banks that specialize in housing loans (H banks) and the banks that specialize in entrepreneurial loans (F banks). Let e_t^F be the amount of the initial wealth n_t^b invested as inside equity in F banks and the rest, $n_t^b - e_t^F$, in H banks. The net worth of the banker in period $t+1$ is $W_{t+1}^b = \tilde{\rho}_{t+1}^F e_t^F + \tilde{\rho}_{t+1}^H\left(n_t^b - e_t^F\right)$, where $\tilde{\rho}_{t+1}^F, \tilde{\rho}_{t+1}^H$ are the ex post gross returns on the inside equity invested in banks F and H respectively. The maximization problem of the banker is to decide on the allocation of their initial wealth in order to maximize the expected wealth:

$$\max_{e_t^F} E_t\left(W_{t+1}^b\right) = E_t z_t^b \left(\tilde{\rho}_{t+1}^F e_t^F + \tilde{\rho}_{t+1}^H \left(n_t^b - e_t^F\right)\right)$$

where z_t^b is an i.i.d. shock to the bankers wealth. An interior solution in which both types of banks receive positive equity requires that $E_t\tilde{\rho}_{t+1}^F = E_t\tilde{\rho}_{t+1}^H = \rho_t$, where ρ_t denotes the required expected gross rate of return on equity investment at time t. This expected return is endogenously determined in equilibrium but it is taken as given by individuals and banks.

Banks

Banks are institutions that provide loans to households and entrepreneurs. There are two types of banks: banks indexed by H are specialized in mortgage loans and banks indexed by F are specialized in corporate loans. Both types of banks ($j = H, F$) issue equity bought by bankers and receive deposits from households.

Each bank maximizes the expected equity payoff, $\pi_{t+1}^j = \omega_{t+1}^j \tilde{R}_{t+1}^j b_t^j - R_t^D d_t^j$, that is, the difference between the return from loans and the repayments due to its deposits, where ω_{t+1}^j is an idiosyncratic portfolio return shock, which is i.i.d. across banks and follows a log-normal distribution with mean one and a distribution function $F^j\left(\omega_{t+1}^j\right)$, b_t^j and $d_t^j$are respectively the loans extended and deposits taken by bank at period t, R_{t+1}^D is the gross interest rate paid on the deposits taken in period t and $\tilde{R}_{t+1}^j$ is the realized return on a well-diversified portfolio of loans of type j.

Each bank faces a regulatory capital constraint:

$$e_t^j \geq \phi_t^j b_t^j$$

where ϕ_t^j is the capital-to-asset ratio of banks of type j. The regulatory capital constraint states that the bank is restricted to back with equity at least a fraction of the loans made in period t. The problem of each bank j can be written as:

$$\pi_{t+1}^{j} = max\{\omega_{t+1}^{j}\tilde{R}_{t+1}^{j}b_t^j - R_t^D d_t^j, 0\}$$

subject to the aforementioned regulatory capital constraint.

In equilibrium, the constraint will be binding so that the loans and deposits can be expressed as $b_t^j = \frac{e_t^j}{\phi_t^j}$ and $d_t^j = (1-\phi_t^j)\frac{e_t^j}{\phi_t^j}$, respectively. Accordingly, the threshold level of ω_t^j below which the bank defaults is $\overline{\omega}_{t+1}^{j} = \left(1-\phi_t^j\right)\frac{R_t^D}{\tilde{R}_{t+1}^{j}}$ and the probability of default of each bank of type j is $F^j(\overline{\omega}_{t+1}^{j})$. Thus, bank default is driven by fluctuations in the aggregate return $\tilde{R}_{t+1}^{j}$ and the bank idiosyncratic shock ω_{t+1}^{j}. In the case in which a bank defaults, its deposits are taken by DIA.

Given the above, the equity payoffs can then be written as:

$$\pi_{t+1}^{j} = \left[\max\{\omega_{t+1}^{j} - \overline{\omega}_{t+1}^{j}, 0\}\right]\left(\frac{\tilde{R}_{t+1}^{j}}{\phi_t^j}\right)e_t^j$$

$$= \left[\int_{\overline{\omega}_{t+1}^{j}}^{\infty}\left(\omega_{t+1}^{j} f^j\left(\omega_{t+1}^{j}\right)\right)d\omega_{t+1}^{j} - \overline{\omega}_{t+1}^{j}\int_{\overline{\omega}_{t+1}^{j}}^{\infty}\left(f^j\left(\omega_{t+1}^{j}\right)\right)d\omega_{t+1}^{j}\right] \times \left(\frac{\tilde{R}_{t+1}^{j}}{\phi_t^j}\right)e_t^j$$

where $f^j(\omega_{t+1}^{j})$ denotes the density distribution of ω_t^j. Then, the equity payoffs can be written as:

$$\pi_{t+1}^{j} = \frac{\left[1-\Gamma^j(\overline{\omega}_{t+1}^{j})\right]\tilde{R}_{t+1}^{j}}{\phi_t^j}e_t^j$$

and the required ex post rate of return from the bankers that invest in the bank j is:

$$\tilde{\rho}_{t+1}^{j} = \frac{\left[1-\Gamma^j(\overline{\omega}_{t+1}^{j})\right]\tilde{R}_{t+1}^{j}}{\phi_t^j},$$

where $\Gamma^j\left(\overline{\omega}_{t+1}^{j}\right) = \int_0^{\overline{\omega}_{t+1}^{j}}\left(\omega_{t+1}^{j} f^j(\omega_{t+1}^{j})\right)d\omega_{t+1}^{j} + \overline{\omega}_{t+1}^{j}\int_{\overline{\omega}_{t+1}^{F}}^{\infty}\left(f^j(\omega_{t+1}^{j})\right)d\omega_{t+1}^{j}$ and

$$G^j\left(\overline{\omega}_{t+1}^{j}\right) = \int_0^{\overline{\omega}_{t+1}^{j}}\left(\omega_{t+1}^{j} f^j(\omega_{t+1}^{j})\right)d\omega_{t+1}^{j}.$$

Finally, the average default rate for banks can be written as:

$$PD_t^b = \frac{d_{t-1}^H F^H(\bar{\omega}_{t+1}^H) + F^F(\bar{\omega}_{t+1}^F)}{d_{t-1}^H + d_{t-1}^F}$$

and the expression for the realized returns on loans after accounting for loan losses can be expressed as:

$$\tilde{R}_{t+1}^H = \left(\Gamma^m\left(\frac{x_t^m}{R_{t+1}^H}\right) - \mu^m G^m\left(\frac{x_t^m}{R_{t+1}^H}\right)\right)\left(\frac{R_{t+1}^H q_t^H h_t^m}{b_t^m}\right)$$

$$\tilde{R}_{t+1}^F = \left(\Gamma^e\left(\frac{x_t^e}{R_{t+1}^K}\right) - \mu^e G^e\left(\frac{x_t^e}{R_{t+1}^K}\right)\right)\left(\frac{R_{t+1}^K q_t^K k_t}{q_t^K k_t - n_t^e}\right)$$

Production sector

The final good in this economy is produced by perfectly competitive firms that use capital, k_t and labour, h_t. The production technology is:

$$y_t = A_t k_{t-1}^a l_t^{1-a}$$

where A_t is total factor productivity and a is the labour share in production.

Capital and housing production

Capital and housing producing firms are owned by patient households. Capital producers combine a fraction of the final good, I_t, and previous capital stock k_{t-1} to produce new units of capital goods that are sold to entrepreneurs at price q_t^K. The law of motion for the physical capital stock is given by:

$$k_t = (1-\delta_t)k_{t-1} + \left[1 - S_K\left(\frac{I_t}{I_{t-1}}\right)\right] I_t$$

where $S_K\left(\frac{I_t}{I_{t-1}}\right) = \frac{\xi_K}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$ is an adjustment cost function that satisfies $S(.) = S'(.) = 0, S''(.) = 0.$

The objective of the representative capital producing firm is to maximize expected profits:

$$E_t \sum_{i=0}^{\infty} (\beta^s)^i (\frac{c_t^S}{c_{t+i}^S}) \{q_{t+i}^K I_{t+i} - [1 + S^K (I_{t+i}/I_{t+i-1})]\, I_{t+i}\}$$

Housing producers are modelled in a similar manner. In particular, the law of motion of the aggregate housing stock is:

$$h_t = (1 - \delta_t^h) h_{t-1} + \left[1 - S_H \left(\frac{I_t^h}{I_{t-1}^h}\right)\right] I_t^h$$

And the maximization problem of the representative housing producing firm is:

$$E_t \sum_{i=0}^{\infty} (\beta^s)^i (\frac{c_t^S}{c_{t+i}^S}) \{q_{t+i}^H I_{t+i}^H - [1 + S^K (I_{t+i}^H/I_{t+\iota-1}^H)]\, I_{t+i}^H\}$$

Macroprudential policy

The macroprudential authority sets the capital requirements on bank lending in period t according to the following rule:

$$\phi_t^j = \bar{\phi}_0^j + \bar{\phi}_1^j [\log(b_t) - \log(\bar{b})]$$

where $\bar{\phi}_0^j$ is the reference level of capital requirements and $\bar{\phi}_1^j > 0$ is a feedback parameter that captures the cyclical adjustments in capital requirements that depends on the state of the economy.

Stochastic environment

Shocks to productivity, housing preferences, the depreciation rates and risk shocks follow an $AR(1)$ stochastic process of the form:

$$lnS_t = \rho^S lnS_{t-1} + \varepsilon_t^S$$

where $S_t = \{A_t, \upsilon_t, \delta_t, \delta_t^H, z_t^b\}$, ρ^S is the persistence parameter and $\varepsilon_t^S \sim (0, \sigma_t^S)$. We also introduce risk shocks in the spirit of Christiano et al. (2014) by allowing the variance of the idiosyncratic shocks to vary over time.

3. Calibration of the model and the long-run solution

The model is calibrated to the Greek economy at a quarterly frequency. The data sources are Eurostat and the Bank of Greece, unless otherwise indicated, and span the period 2003-2010. The calibrated parameters are summarized in Table 1.

In line with Clerc et al. (2015), capital requirements are set at 8% for corporate loans and 4% for mortgage loans.[2] The discount factor for patient households is calibrated using a quarterly interest rate on deposits equal to 0.77% (3.08% annually). As is usual in the related literature, the discount factor for impatient households is set equal to 0.98 and the Frisch elasticity of labour equal to 0.5. The preference parameters that govern the marginal disutility of labour, φ, and the utility weight of housing, υ, are respectively set equal to one and 0.25 for both types of households.

The depreciation rates on capital and housing investment, δ, δ^H, have been respectively set to match as closely as possible the average values of total investment (net of housing) to GDP and housing investment to GDP over the sample period. The labour share is computed from AMECO data that adjusts for the income of the self-employed persons, giving a value equal to 0.6.

We calibrate the parameter of the depositor cost of bank default, γ, to match the average value of the spread between deposit rates and the policy rate, which is used as a proxy for the premium required by depositors in order for them to deposit their money in the risky bank. This gives a value for γ expressed in annual terms equal to 0.24, implying losses of 24% of face value for depositors at failed banks.

The parameters which determine the probabilities of default for household and entrepreneurial loans, σ_H, σ_F are calibrated to pin down the average values of the household debt-to-GDP ratio and the corporate debt-to-GDP ratio found in the data.

[2] As regards corporate loans, this is compatible with the weights of Basel I and with the treatment of non-rated corporate loans in Basel II and III. The capital requirement parameterization for mortgage loans is compatible with their 50% risk-weight in Basel I.

This yields $\sigma_H = 0.1$ and $\sigma_F = 0.5$, implying higher uncertainty in the corporate sector. Following the study of Clerc et al. (2015), we set the parameters that determine the probabilities of default for the two types of banks to imply a default rate equal to 2%. The bankruptcy cost parameters imply losses of 30% of asset value for creditors repossessing assets from defaulting borrowers. The adjustment cost parameters for capital and housing and the shock persistence parameters are those employed in Clerc et al. (2015). The feedback parameter that captures the cyclical adjustments in capital requirements has been set to the lowest possible value so as to ensure that the equilibrium solution is stationary.

Table 2 summarizes the long-run solution of the model, which is in line with key features of the data on the Greek economy and constitutes a reasonable starting point for our experiments.

4. Steady-state analysis

In this section we consider the steady-state effects of: i) changes in the capital requirement ratio; ii) the various risk sources; and iii) the depositor cost of bank default. As explained in the Introduction, ii) and iii) might have played an important role during the recent banking crisis in Greece.

4.1 The steady-state effects of capital requirements

We first consider the long-run effects of capital requirements on key model variables and social welfare. Following e.g. Lucas (1990), the latter is calculated by computing the permanent consumption subsidy that is required in each period so as to make aggregate welfare under the baseline policy ($\phi^F = 0.08$ and $\phi^H = 0.04$) equal to the welfare under alternative values of ϕ^F and ϕ^H. This percentage change in consumption is defined as ζ. If $\zeta > 0$ ($\zeta < 0$), there are welfare gains (losses) relative to the baseline policy. In particular, the reported social welfare gains/losses are a weighted average of the welfare gains/losses of the patient and impatient households:

$$\zeta \equiv \frac{c_0^s}{c_0^s + c_t^m}\zeta^s + \frac{c_0^m}{c_0^s + c_t^m}\zeta^m$$

where c_0^s and c_0^m denote respectively the steady-state consumption of the patient and impatient dynasties under the baseline policy.

As depicted in Figure 1, the steady-state relationship between capital requirements and social welfare exhibits a humped shape similar to that of Clerc et al. (2015) for the euro area, implying a trade-off between capital requirements and welfare. On the one hand, higher capital requirements reduce the average default rate for banks triggering a reduction in deposit insurance costs and an increase in credit supply that improves economic activity. On the other hand, higher capital requirements reduce the supply of funds and that negatively affects economic activity. The optimal capital requirement that maximizes welfare is around 9.6 for business loans (half of that for mortgages). Note that this value is lower than the optimal value of around 10.5 obtained in Clerc et al. (2015) for the euro area. This implies that it may be optimal for Greece to have somewhat looser capital requirements than the euro area average. In addition, welfare gains are eroded far more rapidly in the case of Greece and in fact turn into aggregate welfare losses for levels of ϕ^F greater than 12.5. Thus, in the case of Greece, the negative effects on economic activity stemming from the reduction in credit supply dominate the positive implications of lower default rates earlier than they do in the rest of the euro area.

Figures 2 - 5 illustrate the implications of a change in ϕ^F and ϕ^H for the steady-state values of key variables in the model. Higher capital requirements imply by definition a lower average default rate of banks (Figure 2). This leads to a decline in the deposit insurance subsidy, thus freeing up some resources in the economy. The deposit spread required by the saving households in order for them to deposit their savings in the banks also declines. In other words, as banks become less fragile under the higher capital requirements, depositors require a lower premium in compensation for their anticipated costs of bank default. Up to a point, the beneficial stabilizing effects of an increase in capital requirements lead to an increase in total credit and a boost in consumption and overall economic activity (Figure 4). However, for much higher levels of capital requirements, total credit begins to decline. Households and firms have access to less credit which is provided at higher interest rates (Figure 3). The negative real implications of the decline in credit supply dominate the positive impact of declining bank defaults.

The rate of default and the leverage of entrepreneurs decline at an increasing speed (Figures 2-3). The default rate of households increases more rapidly in the case of Greece compared to the euro area calibrated model of Clerc et al. (2015), and peaks at a higher value of ϕ^F before beginning its downward trend. Similarly, mortgage loans and the leverage of households increase by somewhat more and subsequently decline by less. Note that, in the model, both entrepreneur and household default rates are lower in Greece than in the euro area calibration, and so are commercial and mortgage loans, the former standing at about half of the value reported in Clerc et al. (2015). Finally, turning to Figure 4, we see that the peak in household consumption occurs somewhat earlier in the case of Greece, the increase is smaller as a percentage and the subsequent decline is much larger. Conversely, business and residential investment are affected by much less, as their decline is far smaller in magnitude than that presented for the euro area calibration. In other words, the main mechanism at play is via household consumption.

4.2 The steady-state effects of risk

We undertake a similar exercise to explore how key model variables are affected by changes in the variance of idiosyncratic risk shocks to banks, households and entrepreneurs that might have played an important role in the recent Greek crisis.

Turning first to the effect of an increase in σ_H^2 and σ_F^2, i.e. the variance of idiosyncratic shocks hitting mortgage banks and firm-lending banks respectively, Figures 6-9 present the steady-state implications in two panels. An increase in the variance of shocks hitting banks leads to a decline in aggregate variables, including GDP (Figure 8), at an increasing pace. In both cases this works via an increase in the average default of banks, an associated increase in the premium required by savers in order to deposit their funds at the banks and an increase in deposit insurance costs (Figure 6). As a result banks now lend less, *albeit* at higher interest rates (Figure 7). The leverage of both households and entrepreneurs declines, as do their default rates. Notably, overall the impact of an increase in the variance of idiosyncratic shocks hitting firm-lending banks is more pronounced. For any increase in the variance of bank risk, the economy settles at a steady state characterized by lower levels of GDP, household consumption and investment, both residential and business-related (Figure 8).

We now explore the effects of an increase in σ_m^2 and σ_e^2, the variance of household idiosyncratic risk and entrepreneurial risk respectively. Figures 10-13 present the steady-state implications in two panels. As household idiosyncratic risk increases, so does the rate of household defaults, rapidly. Mortgage-lending banks' equity declines and so does the supply of mortgages to households, leading to a decline in residential investment and economic activity. The interest rate on mortgages increases. The corresponding firm-variables however remain largely unaffected. Total credit declines (Figure 10), as banks have less (or more expensive) access to deposits, and so does leverage in both sectors of the economy (Figure 11). Hence, the economy settles at a steady state where, although household consumption is marginally higher due to a substitution effect, both types of investment and GDP are lower.

As entrepreneurial risk increases, the level of aggregate real variables deteriorates far more rapidly (Figure 12). The rate of default of entrepreneurs increases sharply, while that of households remains unaffected. The rate of default of banks also rises, as a result of the increased defaults in the corporate sector, and so does the deposit spread. The decline in firm-lending bank equity leads to a sharp decline in corporate loans which has a substantial impact on corporate investment and GDP. Total credit declines markedly, reflecting primarily a decline in corporate loans, while the interest rate required on corporate loans increases. Consequently, entrepreneurs become less leveraged. However, it is interesting that an increase in firms' idiosyncratic risk filters' through to the household sector. In particular, mortgage loans are also affected, the magnitude of their decline being similar if not greater than that stemming from a higher variance of household idiosyncratic risk. As a result, residential investment declines, along with consumption. In sum, with higher entrepreneurial risk, all real variables including consumption, investment and GDP are lower. Thus, it is uncertainty in the corporate sector which seems to have the strongest real adverse effects.

4.3 The steady-state effects of the depositor cost of bank default

We now explore the model's steady-state sensitivity to a variable which may have played a material role in the unfolding of the Greek crisis, namely the potential cost of a bank default on depositors. In the model, this cost takes the form of a direct haircut on households' deposits. At the peak of the crisis, Greek banks were perceived to be so fragile that depositors made huge deposit withdrawals, moving their cash savings either to some physical storage space or to overseas banks. The aim of this flight to safety was precisely to avoid a haircut of the type that was imposed on selected depositors in Cyprus, as well as to hedge against the possibility of Greece leaving the euro area which was publicly discussed at the time. In order to gain a better understanding of this period, we consider the effects of higher depositor costs of bank default on the model's steady state. Figures 14-17 illustrate that, as a first order effect, an increase in the depositors' cost of bank default leads to a substantial increase in the deposit spread required by households in order to deposit their savings in the banks and a decline in deposits. This in turn leads to a decline in total credit and leverage, a decline in bank equity and to an increase of bank defaults, as more banks are now unable to meet the higher deposit rate. As a result, all macro variables also clearly decline. This domino effect fits in well with the Greek crisis experience, as indeed deposit withdrawals took a heavy toll on both the stability of the financial sector and real economic activity.

5. Impulse response analysis

5.1 The dynamic effects of a shock to total factor productivity

Figures 18-21 present the dynamic responses of key variables to a temporary negative one percent shock to total factor productivity, under different parameterisations. In particular, we compare the benchmark economy with an economy with i) higher financial distress in the banking sector and ii) higher capital requirements. Under the benchmark calibration, the shock leads to a decrease in aggregate demand and output. Households incur a negative wealth effect which induces them to decrease current consumption. The decrease in the marginal productivity of capital depresses investment demand and thus the price of both housing and capital. Given that, in the model, these assets constitute collateral against which loans have been pledged, this decline in asset prices leads to increased rates of default for both households and entrepreneurs who now find that this is their optimal strategy. As a result, banks' equity capital also declines. The implications are twofold. Firstly, total credit shrinks, generating a negative second order feedback effect on GDP. Secondly, the rate of bank defaults increases, pushing up the cost of deposit funding. This feeds into lending rates, further depressing both total credit and collateral valuations. This leads to further borrower defaults, setting a vicious circle in motion.

We use a dashed red line to plot the dynamic effect of the same temporary shock under high financial distress (Figures 18-19) and under high capital requirements (Figures 20-21). We find that under high financial distress (i.e. imposing a 30% higher volatility for bank-specific idiosyncratic risk shocks) the impact of a temporary negative TFP shock is more detrimental. The decrease in banks' net worth is greater and more protracted, as is the increase in bank defaults. As a result, credit declines more sharply and takes longer to rebound, negatively affecting the trajectory of GDP, consumption and investment. Conversely, high capital requirements affect the dynamic responses of all key variables in the opposite direction. This implies that macroprudential policy has a buffering effect on the real economy, acting to smooth the adverse effects of exogenous negative real shocks.

5.2 The dynamic effects of a shock to bankers' wealth

We proceed to explore the dynamic effects of a temporary positive one percent shock to bankers' wealth, in an analogous manner (Figures 22-25). This can be thought of as akin to an exogenously funded bank recapitalization. Greek banks were indeed recapitalized several times, with the aim to alleviate the possibility of bank defaults, stabilize the financial system and create the conditions for a recovery of credit flows to the real economy. Within the context of the 3D model, a positive shock to bankers' wealth is mapped into higher bank capital. As a result, there is an increase in total credit which has a positive effect on capital investment. The price of capital increases, implying fewer strategic defaults by entrepreneurs and thus even stronger bank balance sheets. The decline in bank defaults also prompts a fall in the cost banks must pay to attract deposit funding. This passes through, lowering lending rates and further boosting total credit. These second order positive effects create a virtuous circle. The improved creditworthiness of the banking sector prompts an increase in deposits and a concurrent decline in consumption and housing investment, which are crowded out. The net effect on GDP is however clearly positive.

As before, we use a dashed red line to plot the dynamic effect of the same temporary shock under high financial distress (Figures 22-23) and under high capital requirements (Figures 24-25). We find that under high financial distress both the average rate of bank default and the deposit premium decline by much less. As a consequence, the positive real and financial impact of a recapitalization is smaller and more short-lived. Conversely, operating via the same channels, higher capital requirements accentuate the positive real impact of a bank recapitalization.

By analogy, a negative shock to bankers' wealth would mimic the impact of the sharp decline in banks' net worth recorded several times during the recent crisis in Greece. The resulting dynamic effects would provide insights into how this negative shock filtered through to the real economy.

5.3 The dynamic effects of a depreciation shock

The dynamic effects of a temporary negative shock to the rates of depreciation, δ_t and δ_t^H, that is, to the value of the stocks of housing and physical capital, are presented in Figures 26 and 27. The first order effect of such a shock is a decline in the price of housing and capital, which constitute collateral for bank loans. As a result, more households and entrepreneurs find it optimal to default on their debt obligations, depressing banks' net worth as they do so. This has two dynamic implications. Firstly, credit supply begins a protracted decline, with negative effects

on GDP. Secondly, bank defaults become more frequent. This pushes the cost of deposit funding upwards, further raising lending rates. Both channels further depress the price of housing and capital, generating a negative spiral. The effect of this shock on both financial and real variables is substantial and persistent.

5.4 The dynamic effects of risk shocks

The dynamic effects of a temporary negative shock to the variance of idiosyncratic bank risk can be seen in Figures 28 and 29. The immediate effect is an increase in bank defaults. This is propagated via the net worth channel, depressing bankers' net worth and thus restricting total credit to the economy and reducing output through both consumption and investment. The bank funding cost channel also comes into play. The banks' cost of deposit funding increases, pushing lending rates up and further limiting the flow of credit to the real economy.

The effects of an analogous shock to entrepreneurs is depicted in Figures 30 and 31. Here the transmission of the shock operates first through an increase in the rate of default of entrepreneurs. This leads to a decline in capital investment and the price of capital, which negatively affects GDP. The increase in the rate of corporate default leads to an increase in bank defaults, as it weakens their balance sheets.

Credit supply declines as a result, prompting an additional decline in output and further corporate defaults. The cost of deposit funding faced by banks also leads to higher lending rates, further reducing the supply of credit. Figures 32 and 33 plot the dynamic effects of both households and entrepreneurs receiving a negative risk shock, which is arguably what happened in Greece during the recent crisis. The negative effects are naturally compounded.

6. Conclusion

In this paper we have examined the macroeconomic and welfare implications of banking capital requirement policies and their interactions with real and financial shocks for the Greek economy. We adopted the model of Clerc et al. (2015), a DSGE model that features a detailed financial sector, banking capital regulations and bank defaults. We calibrated the model to the Greek economy and examined the long-run effects of banking capital requirements on key model variables, as well as the dynamic responses to a number of financial and real shocks which may have played a material role in the unfolding of the Greek crisis.

The results showed that for Greece, as for the euro area, bank capital requirements reduce bank leverage and the default risk of banks. The relationship between the bank capital requirement ratio and social welfare is hump-shaped, implying a trade-off. In particular, for low levels of the capital requirement ratio, an increase in this ratio leads to a rise in total credit and boosts economic activity. However, when capital requirements are too high, total credit begins to decline, dominating the positive impact of declining bank defaults. Moreover, under high financial distress banks are more vulnerable to shocks and their capacity to supply credit is more volatile. In such a context, bank capital requirements seem to have a buffering effect on the real economy and can smooth the adverse effects of exogenous shocks.

Additionally, we explore the steady-state implications of a depositor bail-in of banks, i.e. of a non-trivial probability that depositors suffer haircuts when their bank defaults, as is now foreseen as a resolution tool in the EU Bank Recovery and Resolution Directive (2014/59) which entered into force in January 2016. Such a development was also perceived as highly likely during the Greek crisis, especially following the depositor bail-in of selected systemic Cypriot banks. In line with Greek experience, we find that an increase in the depositors' cost of bank default leads to a substantial increase in the deposit rate, a decline in deposits and bank equity and an increase in bank fragility while, on the real side of the economy, the decline in total credit prompts a deterioration of key macro variables.

Finally, in view of the repeated recapitalisations of Greek banks in recent years, we explore whether the model can provide relevant insights. We find that recapitalizations can indeed increase bank net worth and credit supply and thus boost economic activity. However, this potential benefit is severely compromised in a high financial distress scenario, as the positive real and financial implications of a bank recapitalization become both smaller and more short-lived. This is a novel and intuitive finding. Moreover it captures well recent experience in the Greek banking sector, where systemic banks had to be repeatedly recapitalized precisely because the gains from each recapitalization were quickly eroded within the highly uncertain financial environment which prevailed at the time.

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9. Tables and Figures

Table 1. Calibrated parameters

Description	Parameter	Value
Patient Household Discount Factor	β^s	0.992
Impatient Household Discount Factor	β^m	0.98
Patient Household Utility Weight of Housing	υ^m	0.25
Impatient Household Utility Weight of Housing	υ^s	0.25
Patient Household Marginal Disutility of Labor	φ^s	1
Impatient Household Marginal Disutility of Labor	φ^m	1
Inverse of Frisch Elasticity of Labor	η	0.2
Depositor Cost of Bank Default	γ	0.242
Variance of Household Idiosyncratic Shocks	σ_m^2	0.1
Household Bankruptcy Cost	μ^m	0.3
Dividend Payout of Entrepreneurs	χ^e	0.06
Variance of Entrepreneurial Risk Shock	σ_e^2	0.5
Entrepreneur Bankruptcy Cost	μ^e	0.3
Capital Requirement for Mortgage Loans	$\overline{\phi}^H$	0.04
Capital Requirement for Corporate Loans	$\overline{\phi}^F$	0.08
Mortgage Bank Bankruptcy Cost	μ^H	0.3
Corporate Bank Bankruptcy Cost	μ^F	0.3
Capital Share in Production	α	0.4
Capital Depreciation Rate	δ	0.025
Capital Adjustment Cost Parameter	ξ^K	2
Housing Depreciation Rate	δ^H	0.015
Housing Adjustment Cost Parameter	ξ^H	2
Shocks Persistence	ρ	0.9
Dividend Payout of Bankers	χ^b	0.06
Variance of Mortgage Bank Risk Shock	σ_H^2	0.01669
Variance of Corporate Bank Risk Shock	σ_F^2	0.0339

Table 2. Long run solution

Description	Data averages	Long run solution
Total consumption over GDP	0.64	0.5426
Investment (related to the capital good production) /over GDP	0.145	0.1386
Investment in housing/over GDP	0.084	0.0791
The premium required by the depositor in order to deposit his money in the risky bank	0.55	0.50
Borrowing spread for entrepreneurs	2.74	1.7243
Borrowing spread for households	1.25	0.8617
Debt of entrepreneurs over debt of households	1.226	1.2514
Debt-to-GDP ratio of entrepreneurs (annualized)	0.491	0.5031
Debt-to-GDP ratio of borrowers (annualized)	0.421	0.4021
Default rate - mortgages	-	0.34
Default rate - entrepreneurs	-	13.86
Default rate - firm lending banks	-	2.04
Default rate - mortgage lending banks	-	2.06

Figure 1. Steady-state welfare depending on the capital requirement

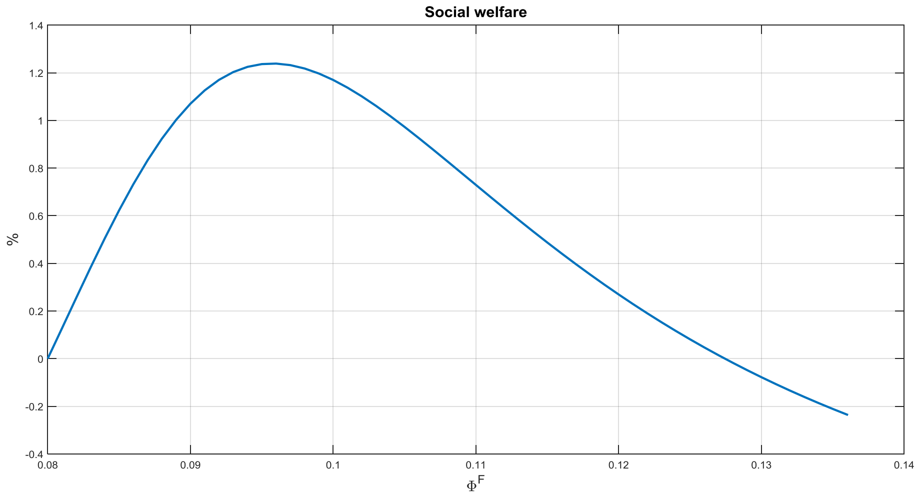
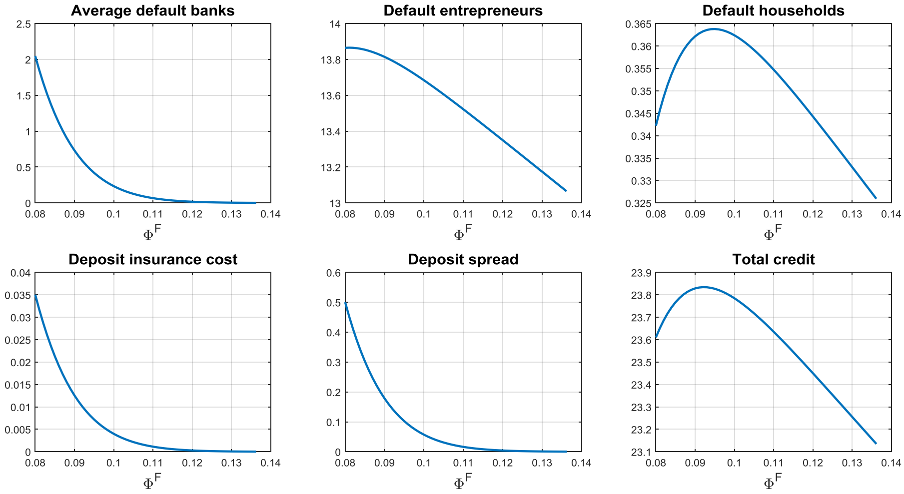


Figure 2. Steady-state values depending on the capital requirement (I)

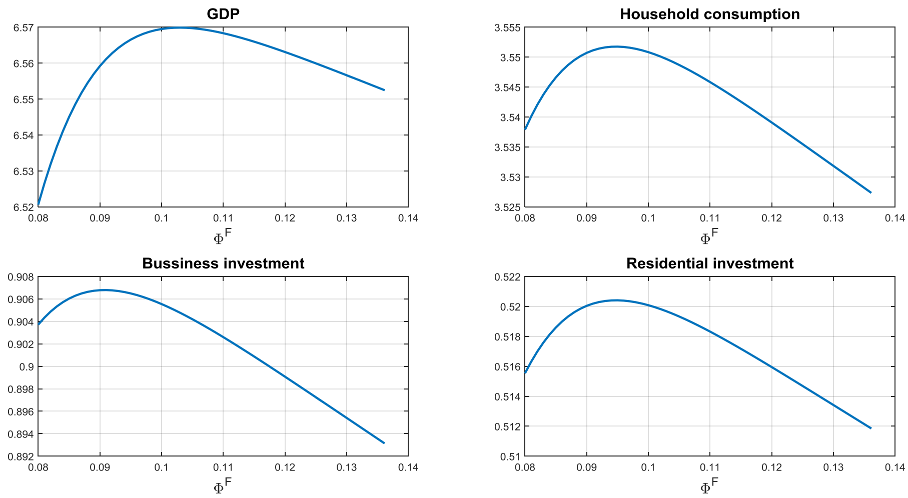


Note: Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$

Figure 3. Steady-state values depending on the capital requirement (II)

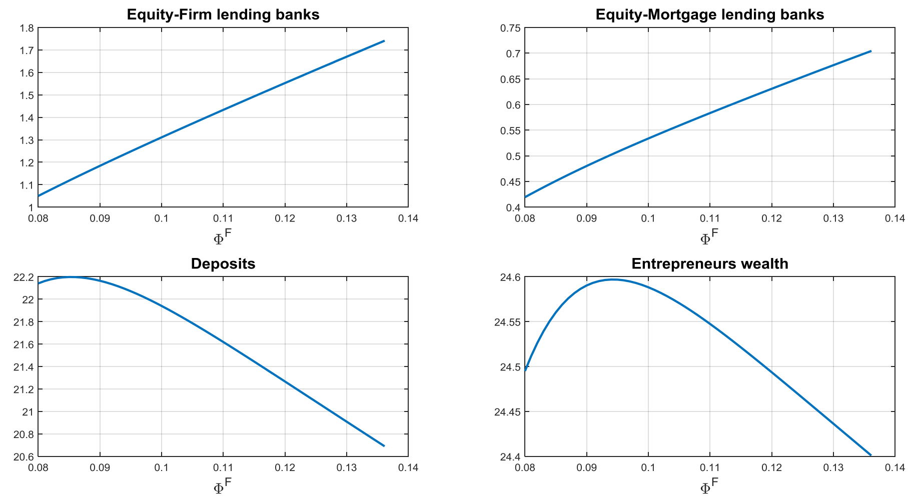
Note: Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$

Figure 4. Steady-state values depending on the capital requirement (III)



Note: Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$

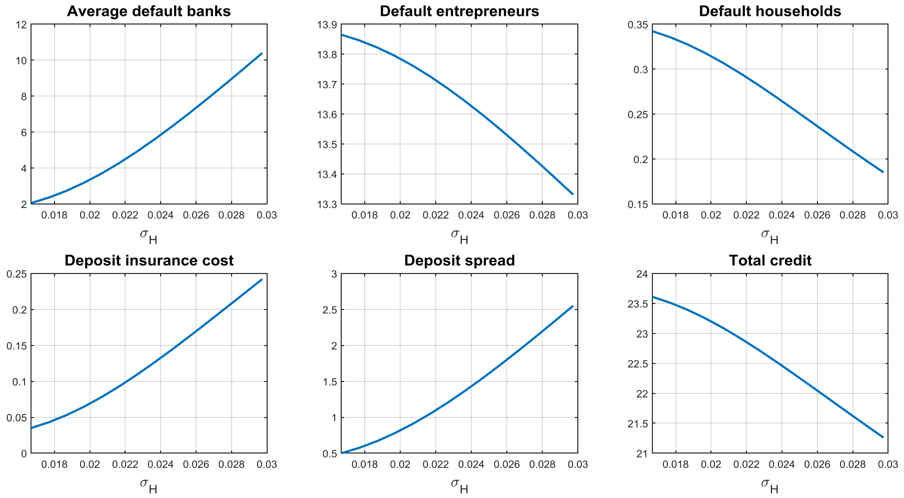
Figure 5. Steady-state values depending on the capital requirement (IV)



Note: Alternative policies involve the value of ϕ^F in the horizontal axis with $\phi^H = \phi^F / 2$

Figure 6. Steady-state values depending on the variance of bank risk shocks (I)

Panel A – Mortgage lending banks



Panel B – Firm lending banks

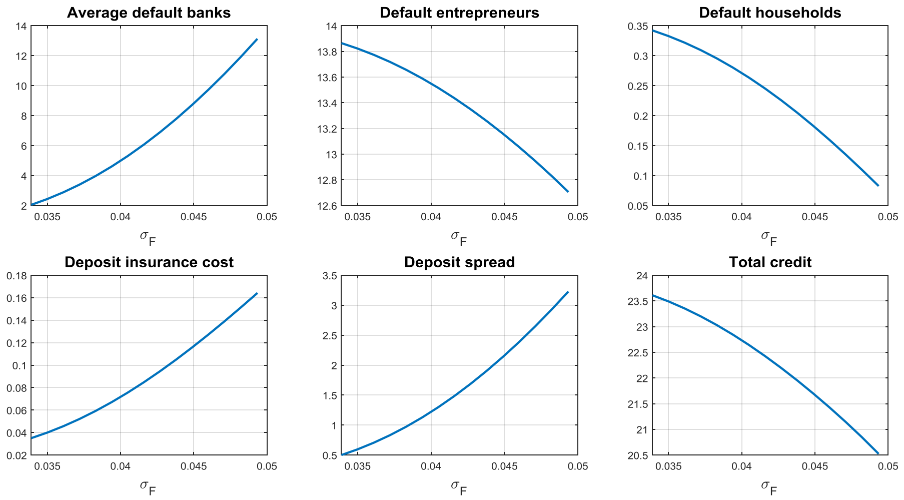
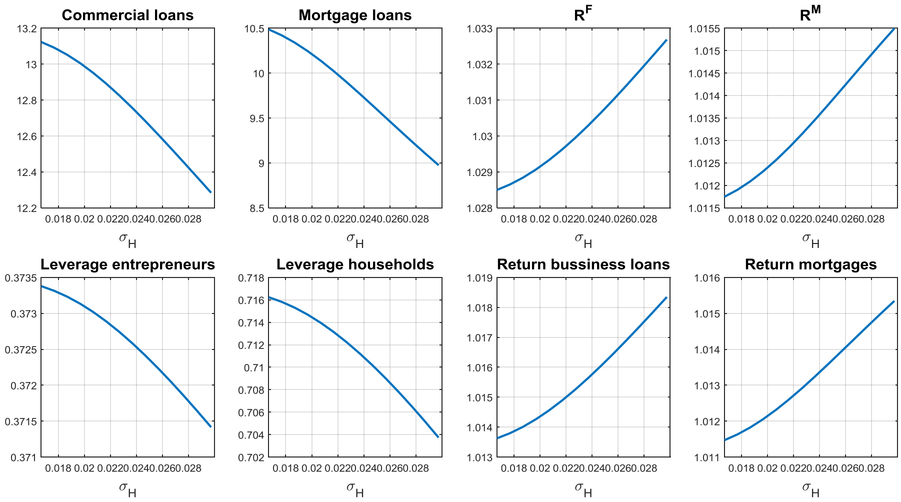


Figure 7. Steady-state values depending on the variance of bank risk shocks (II)

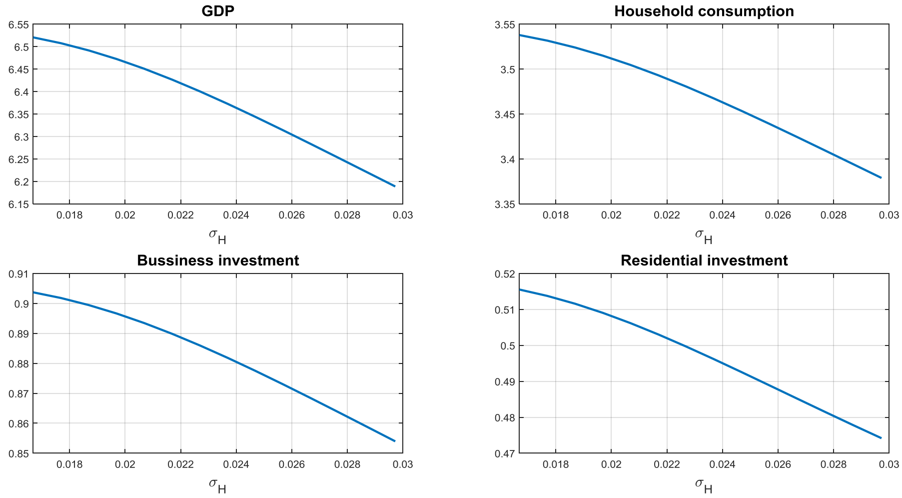
Panel A – Mortgage lending banks



Panel B – Firm lending banks

Figure 8. Steady-state values depending on the variance of bank risk shocks (III)

Panel A – Mortgage lending banks



Panel B – Firm lending banks

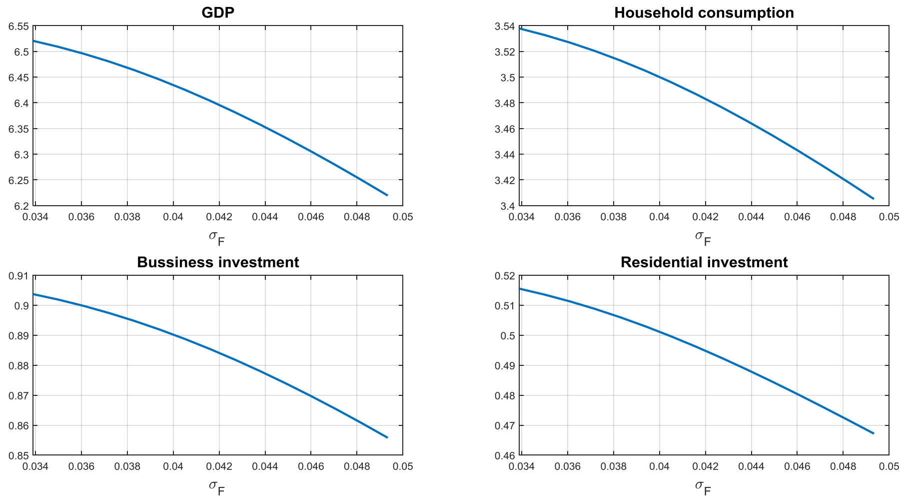
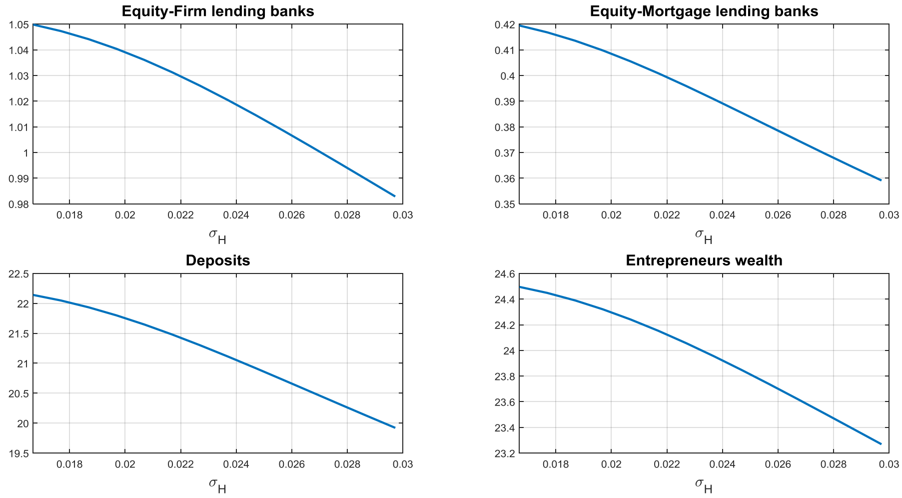


Figure 9 Steady-state values depending on the variance of bank risk shocks (IV)

Panel A – Mortgage lending banks



Panel B – Firm lending banks

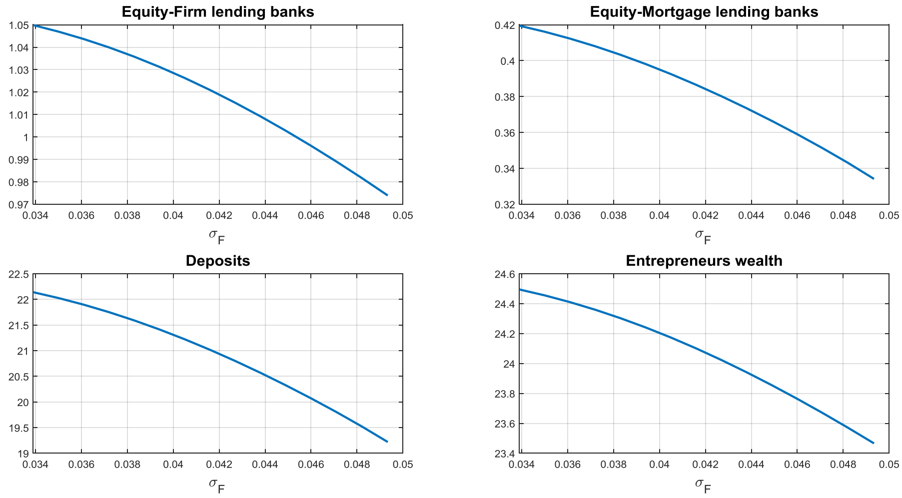
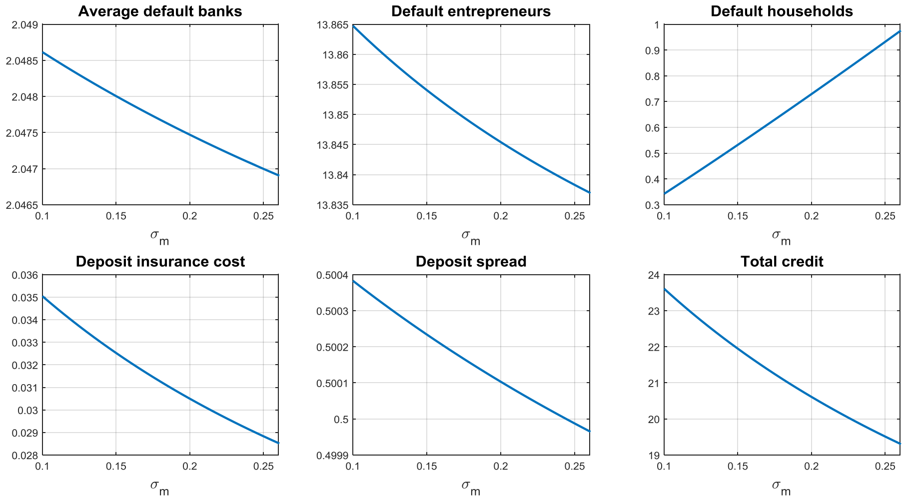


Figure 10. Steady-state values depending on the variance of shocks to households and firms (I)

Panel A – Household risk



Panel B – Entrepreneurial risk

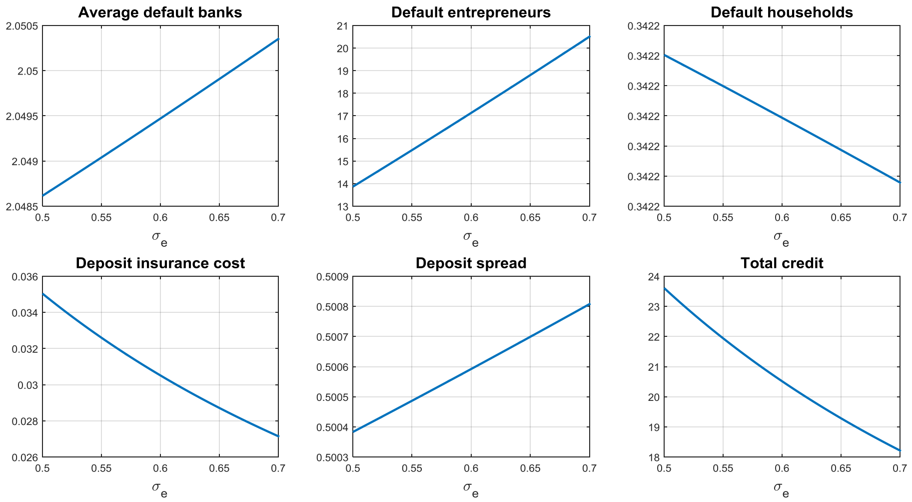
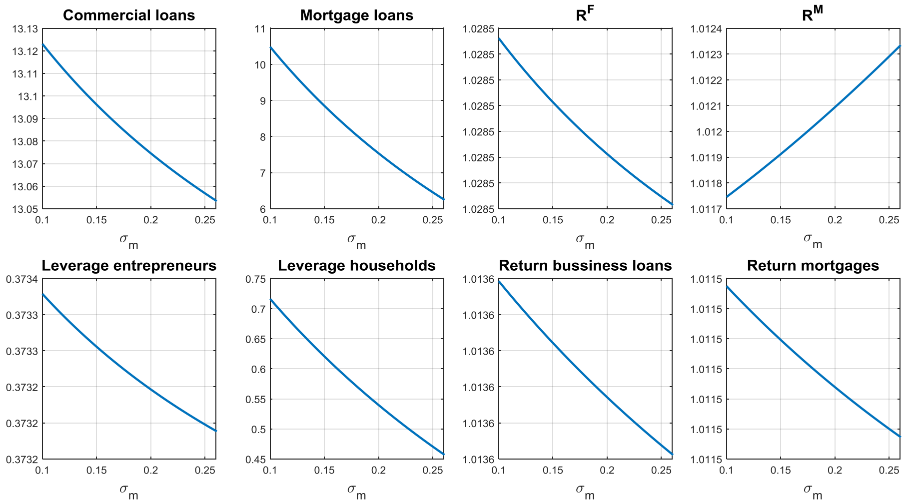


Figure 11. Steady-state values depending on the variance of shocks to households and firms (II)

Panel A – Household risk



Panel B – Entrepreneurial risk

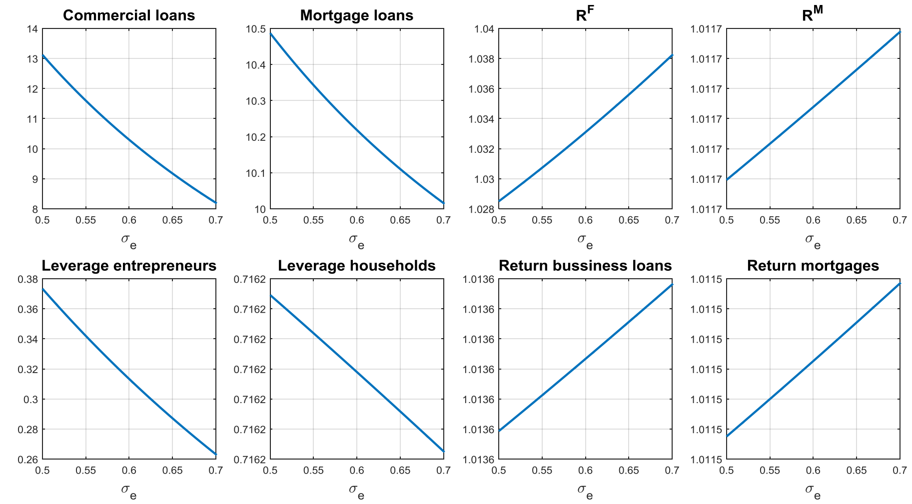
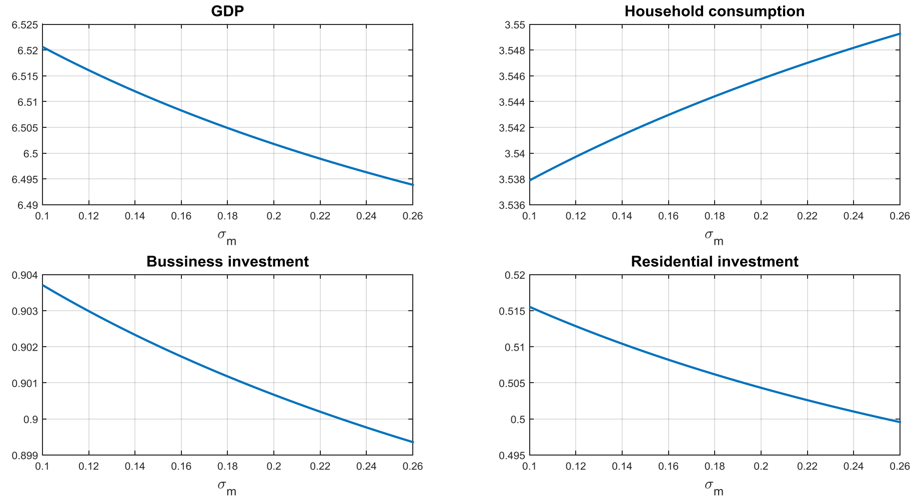


Figure 12. Steady-state values depending on the variance of shocks to households and firms (III)

Panel A – Household risk



Panel B – Entrepreneurial risk

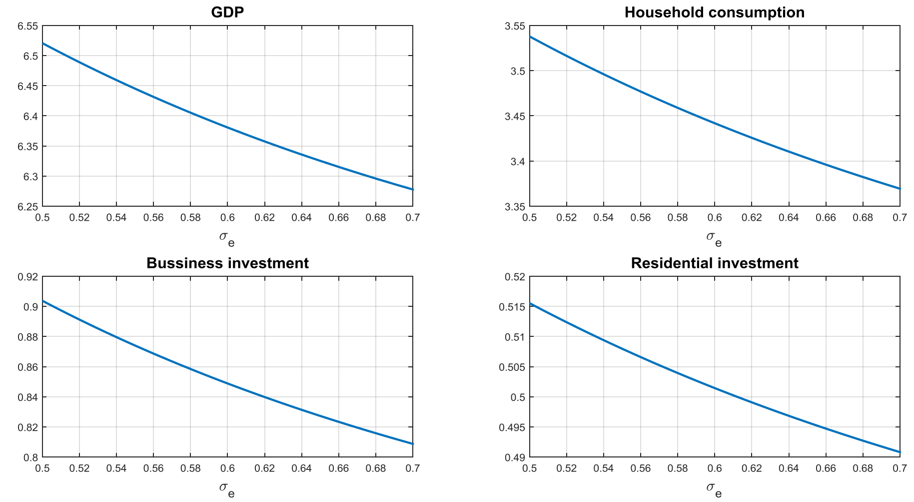
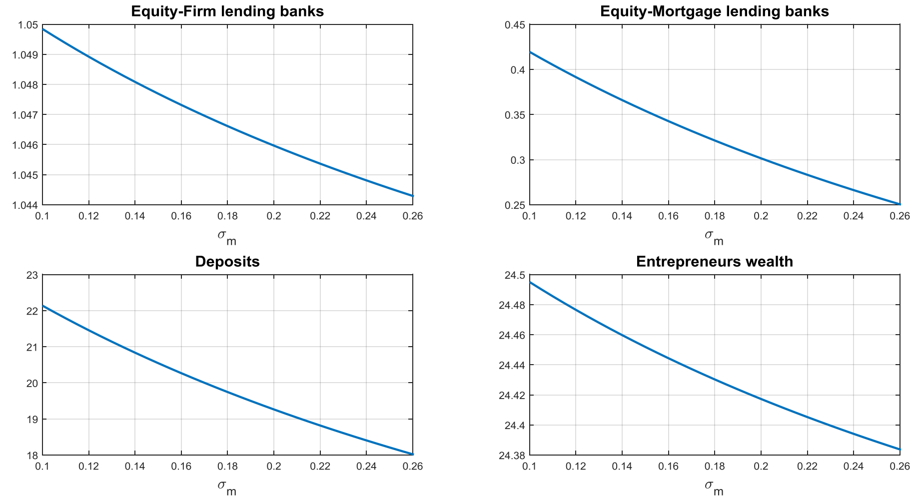


Figure 13. Steady-state values depending on the variance of shocks to households and firms (IV)

Panel A – Household risk



Panel B – Entrepreneurial risk

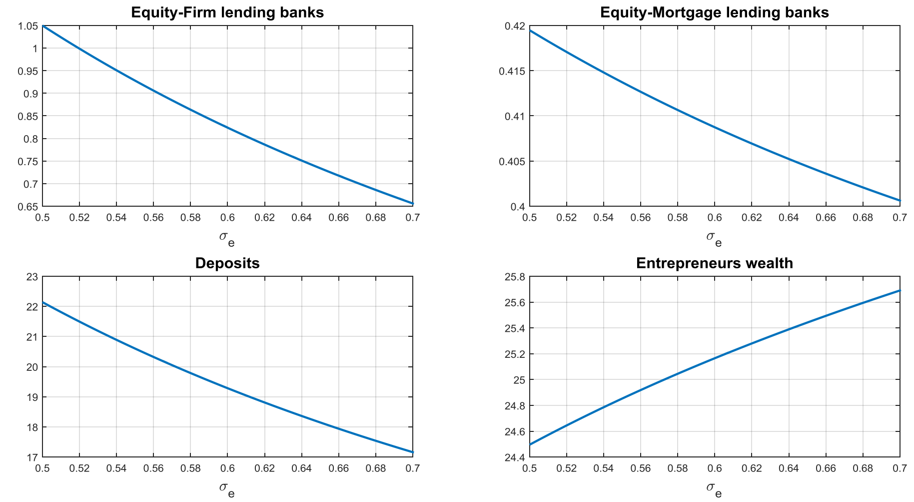


Figure 14. Steady-state values depending on depositor cost of bank default (I)

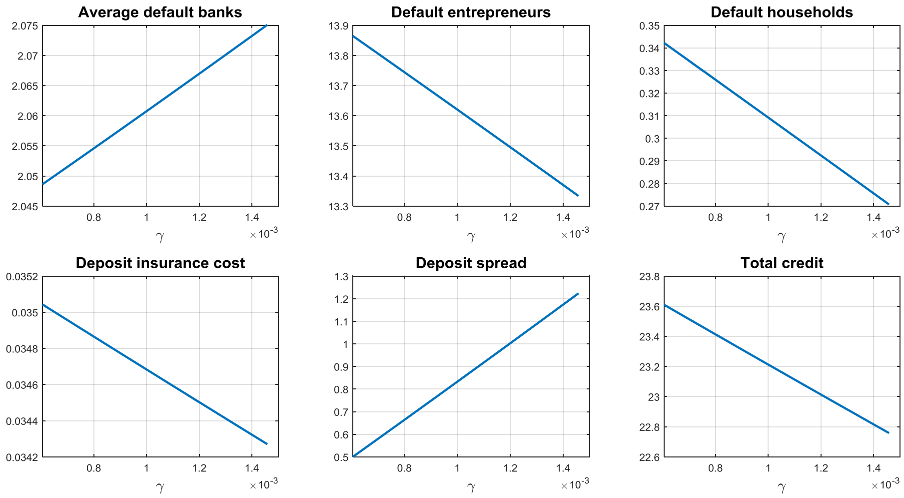


Figure 15. Steady-state values depending on depositor cost of bank default (II)

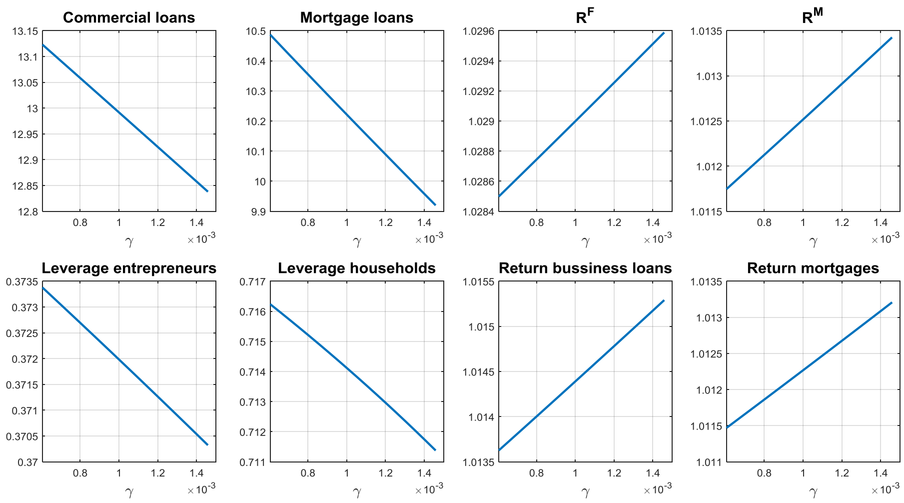


Figure 16. Steady-state values depending on depositor cost of bank default (III)

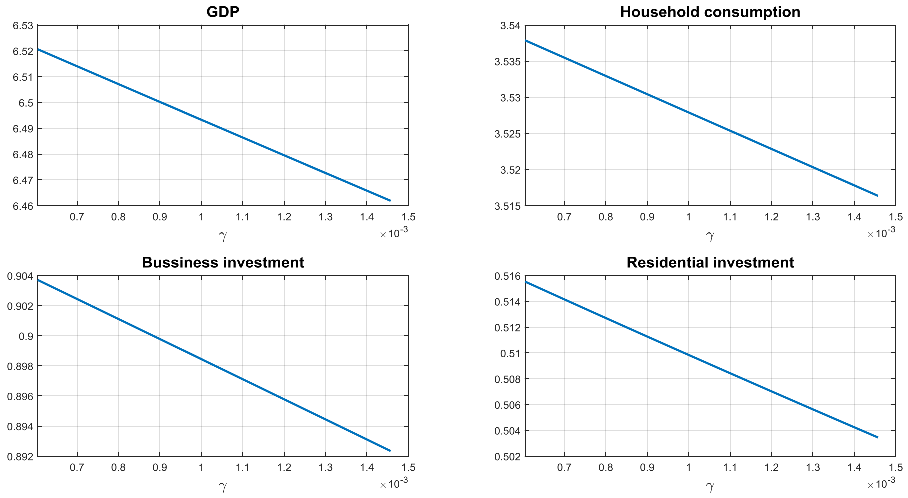


Figure 17. Steady-state values depending on depositor cost of bank default (IV)

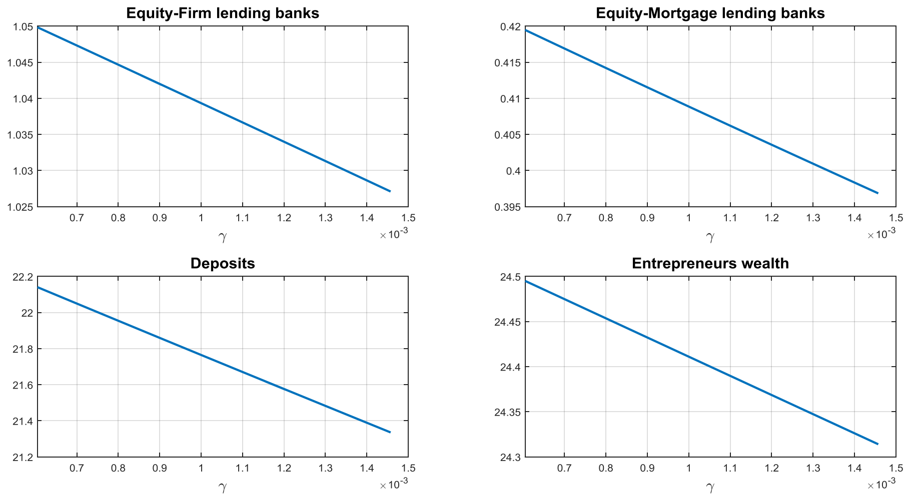


Figure 18. Dynamic effects of a negative TFP shock - High financial distress (I)

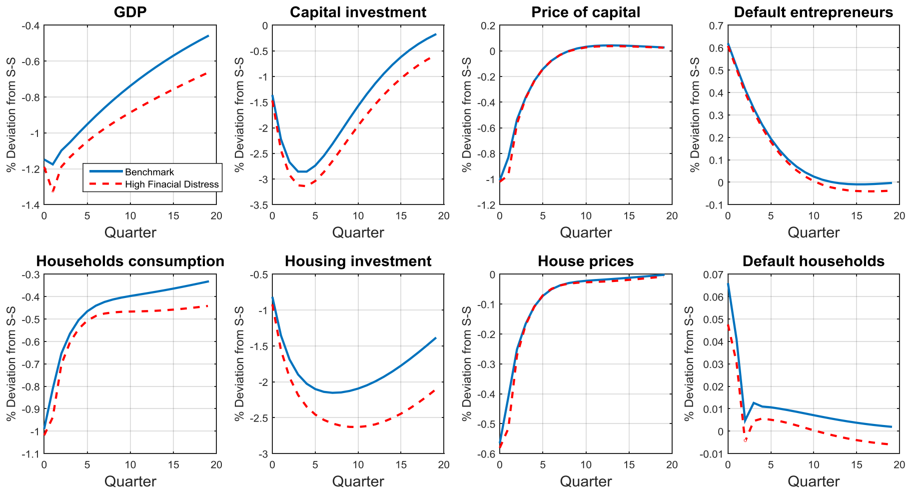


Figure 19. Dynamic effects of a negative TFP shock - High financial distress (II)

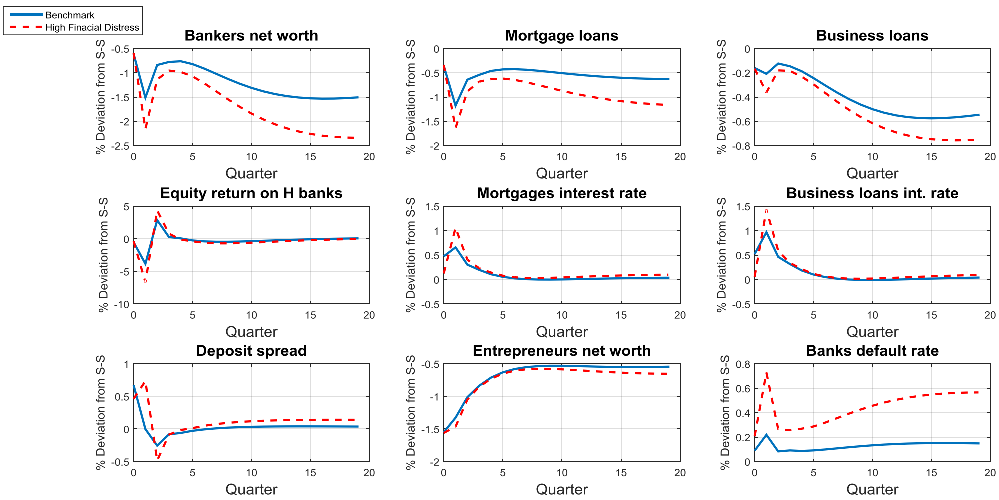


Figure 20. Dynamic effects of a negative TFP shock - High capital requirements (I)

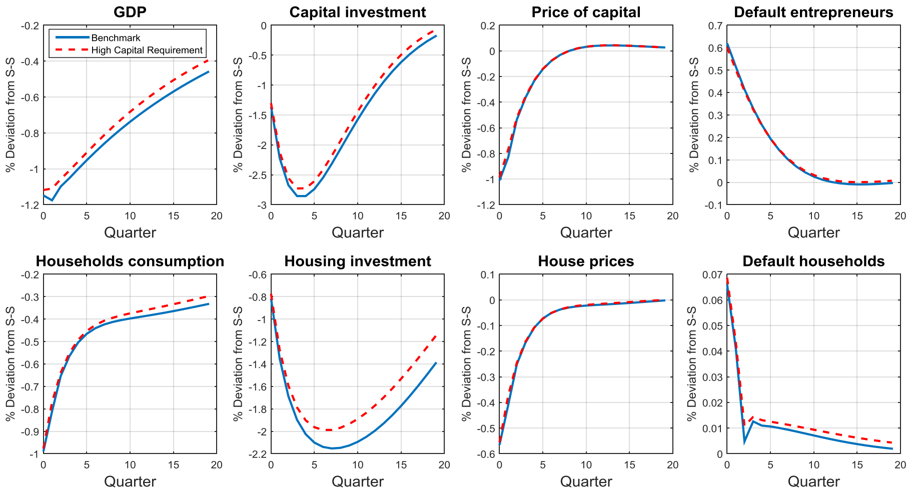


Figure 21. Dynamic effects of a negative TFP shock - High capital requirements (II)

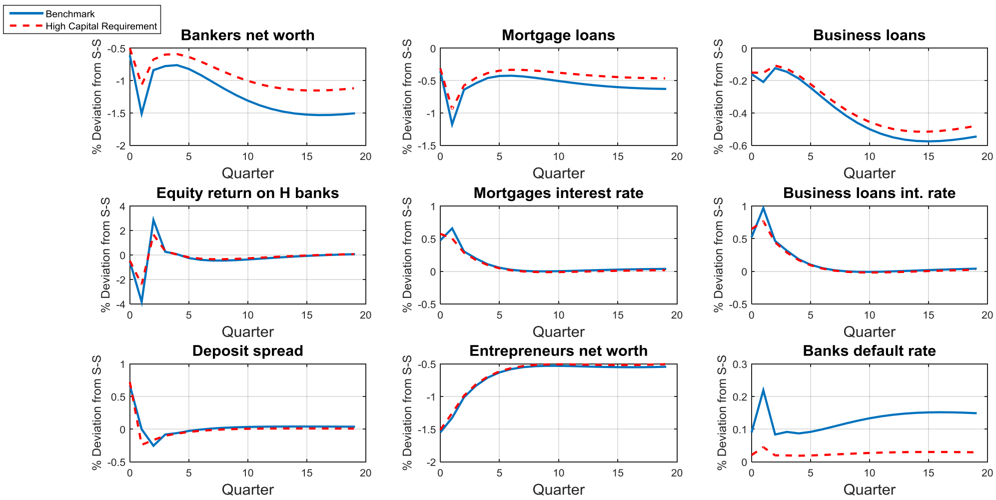


Figure 22. Dynamic effects of a positive shock to bankers' wealth - High financial distress (I)

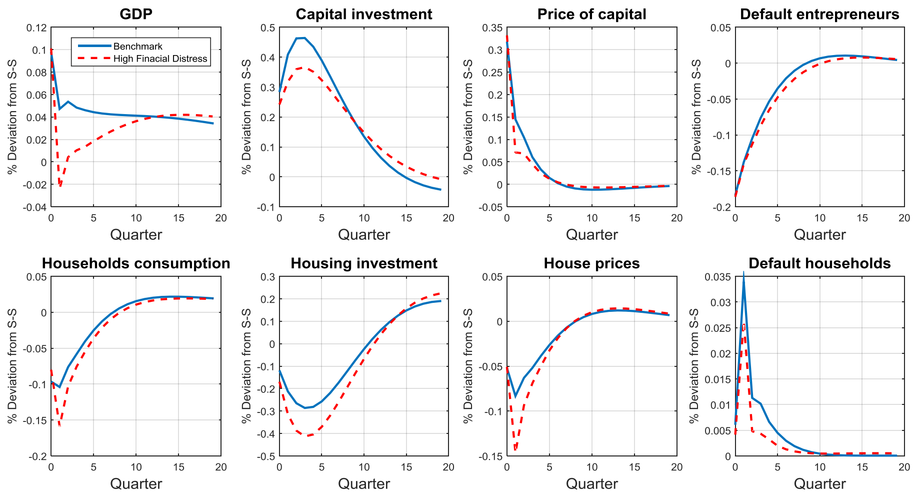


Figure 23. Dynamic effects of a positive shock to bankers' wealth - High financial distress (II)

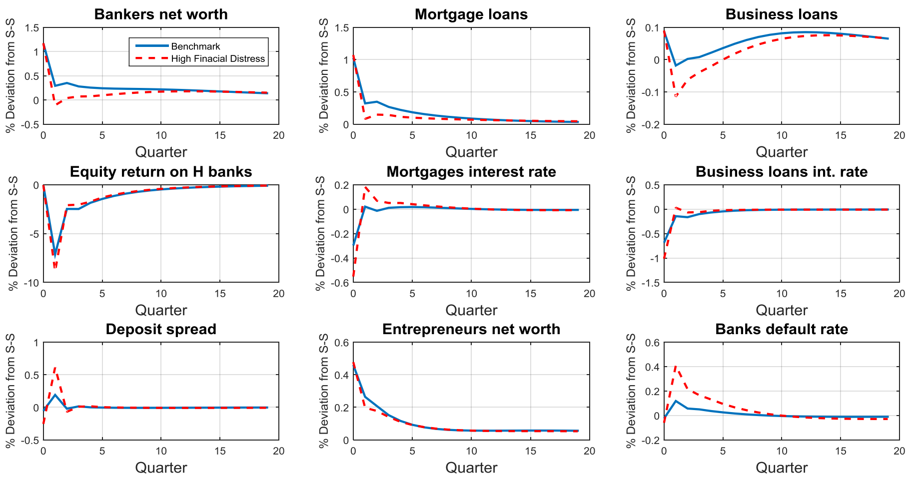


Figure 24. Dynamic effects of a positive shock to bankers' wealth - High capital requirements (I)

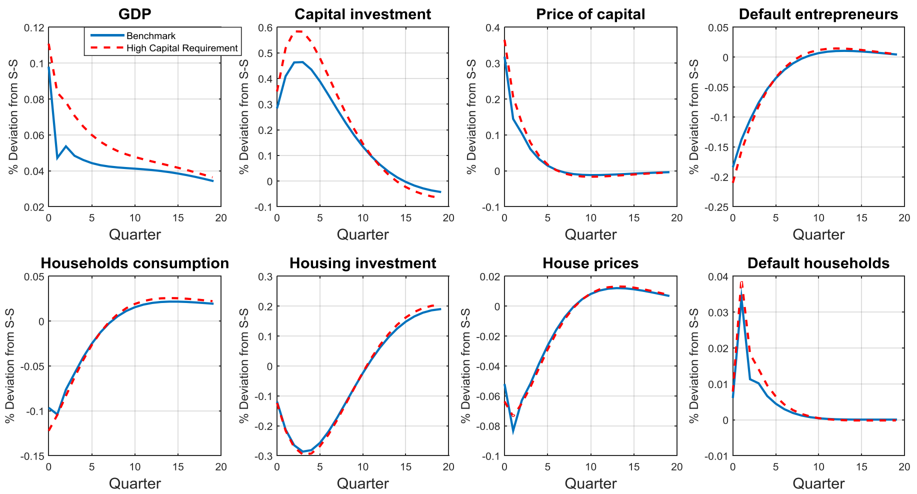


Figure 25. Dynamic effects of a positive shock to bankers' wealth - High capital requirements (II)

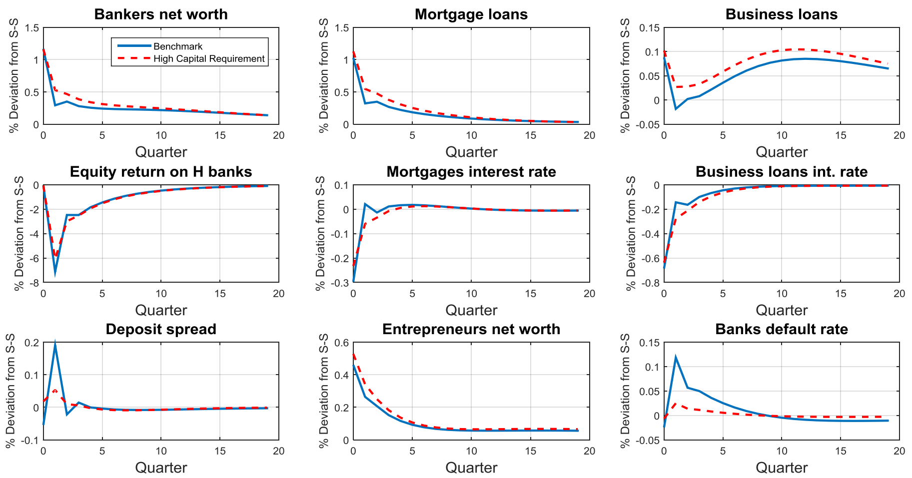


Figure 26. Dynamic effects of a negative depreciation shock (I)

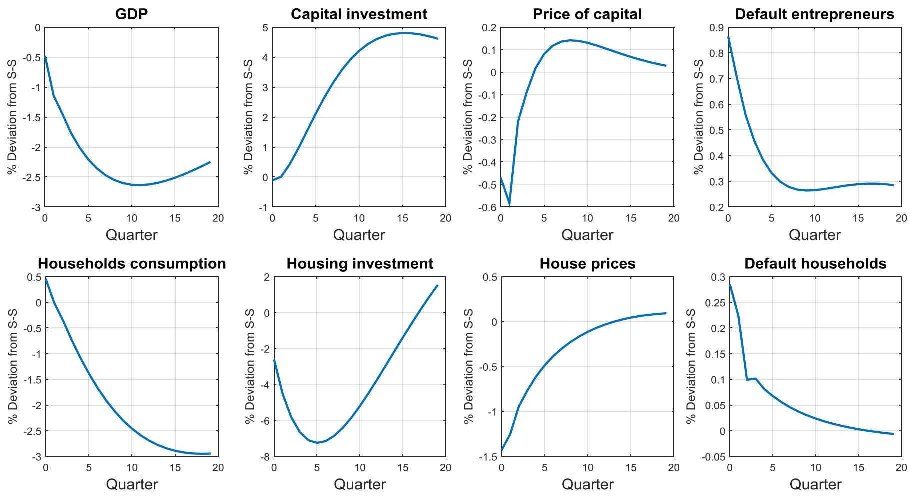


Figure 27. Dynamic effects of a negative depreciation shock (II)

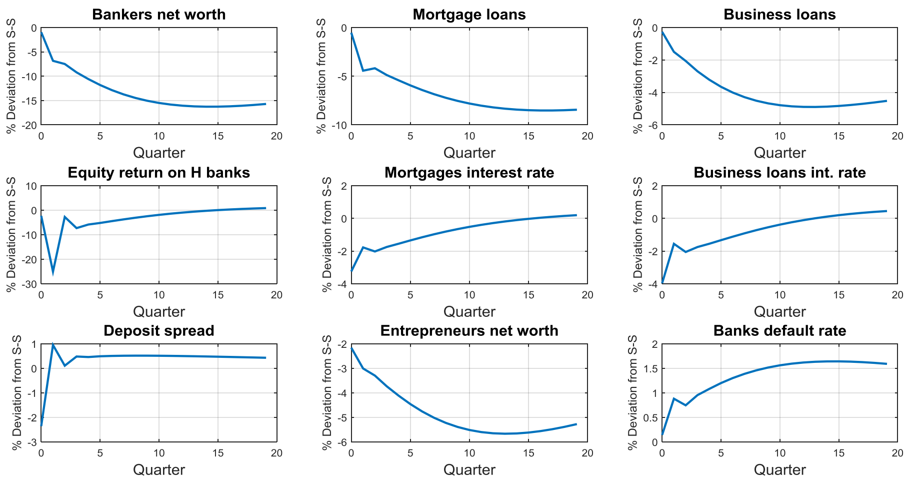


Figure 28. Dynamic effects of a bank risk shock (I)

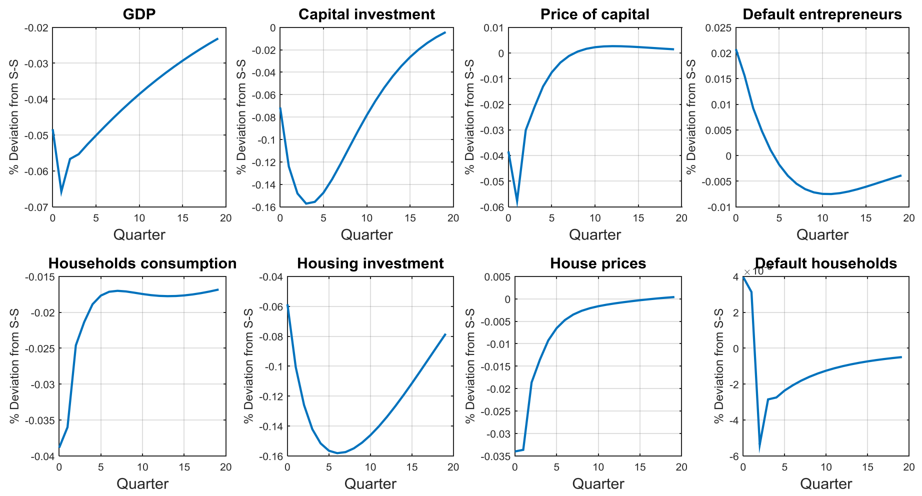


Figure 29. Dynamic effects of a bank risk shock (II)

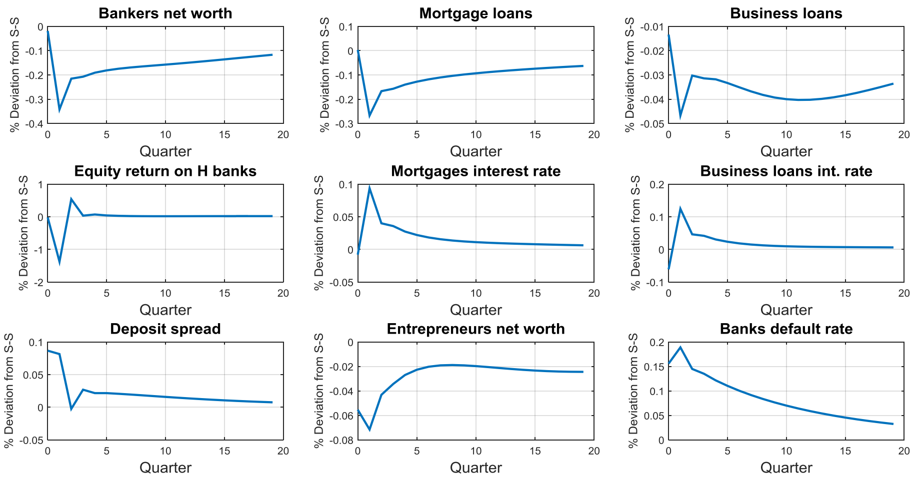


Figure 30. Dynamic effects of a risk shock to entrepreneurs (I)

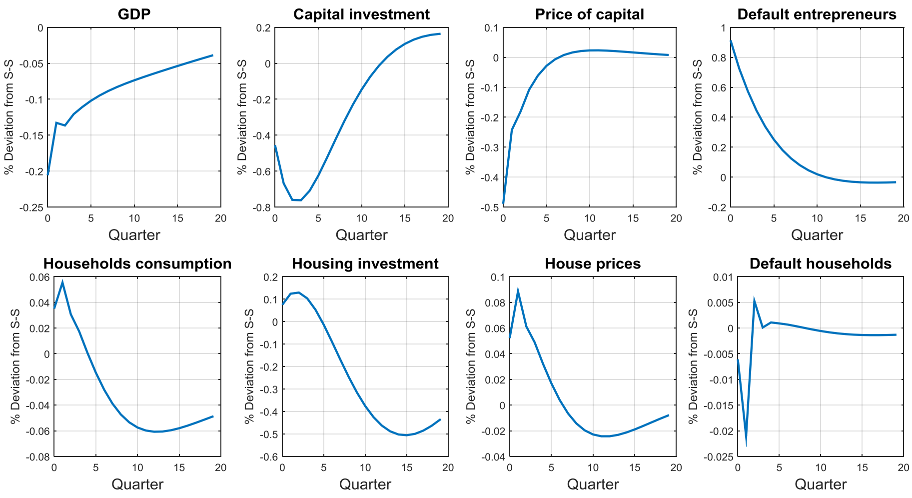


Figure 31. Dynamic effects of a risk shock to entrepreneurs (II)

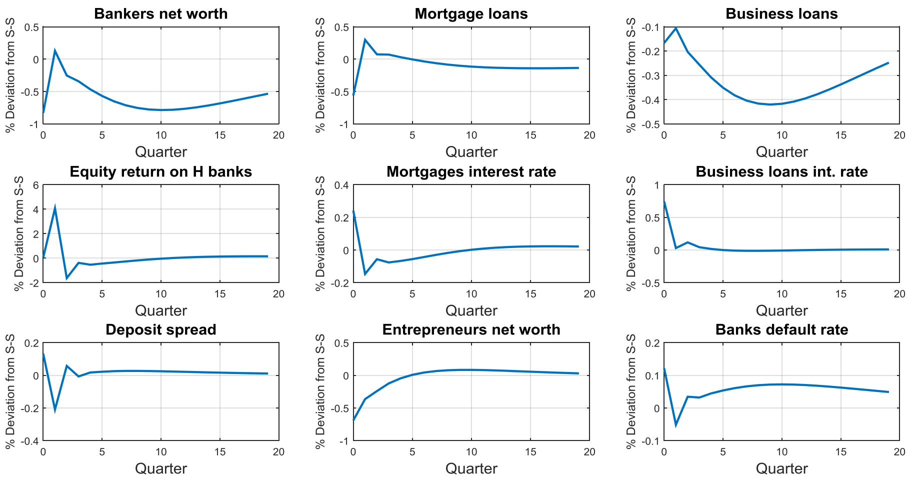


Figure 32. Dynamic effects of a risk shock to all agents (I)

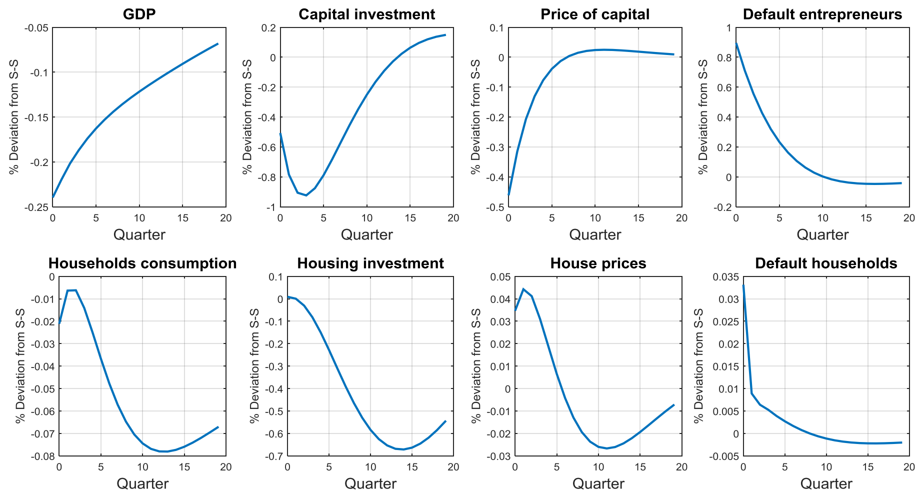
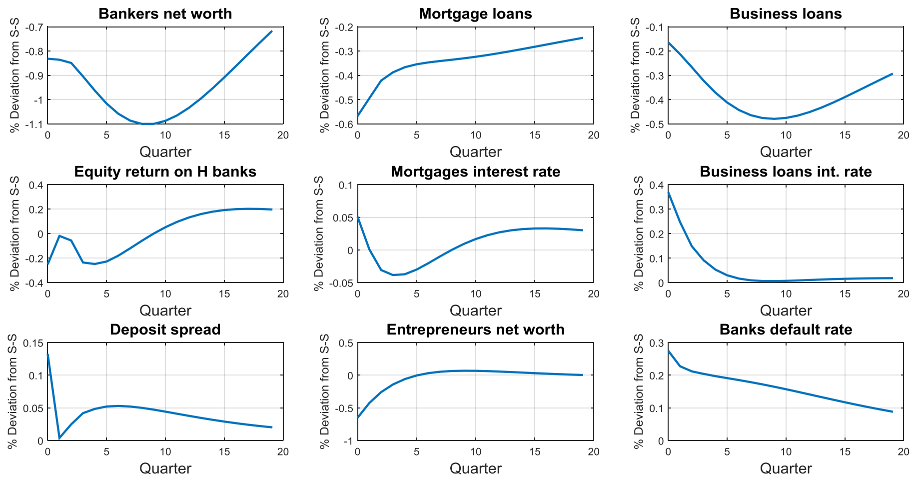


Figure 33. Dynamic effects of a risk shock to all agents (II)



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